CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE

DAM & RESERVOIR

MIDDLE BRANCH, WESTFIELD RIVER, MASSACHUSETTS

DESIGN MEMORANDUM NO. I

HYDROLOGY & HYDRAULIC ANALYSIS

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS WALTHAM, MASS.

APRIL 1961

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

ADDRESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO.

NEDGW

25 April 1961

SUBJECT: Littleville Reservoir, Middle Branch Westfield River, Connecticut River Basin, Massachusetts, Design Memorandum No. I, Hydrology and Hydraulic Analysis

TO: Chief of Engineers
Department of the Army
Washington 25, D. C.
ATTENTION: ENGCW-E

There are submitted herein for review and approval ten (10) copies of Design Memorandum No. I, Hydrology and Hydraulic Analysis, for the Littleville Dam and Reservoir, Connecticut River Basin in accordance with EM 1110-2-1150.

FOR THE DIVISION ENGINEER:

John Wm. Leslie

JOHN WM. LESLIE
Chief, Engineering Division

1 Incl (10 cys)
Des. Memo No. I

DUAL - PURPOSE FLOOD CONTROL AND WATER SUPPLY PROJECT

LITTLEVILLE DAM AND RESERVOIR

MIDDLE BRANCH, WESTFIELD RIVER

CONNECTICUT RIVER BASIN

MASSACHUSETTS

INDEX

* Initial submission in draft to secure approval of spillway design flood and top of dam.

LITTLEVILLE DAM AND RESERVOIR

MIDDLE BRANCH WESTFIELD RIVER
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MASSACHUSETTS

DESIGN MEMORANDUM NO. I
HYDROLOGY AND HYDRAULIC ANALYSIS

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DESIGN MEMORANDUM NO. I

HYDROLOGY AND HYDRAULIC ANALYSIS

A. PURPOSE

1. Purpose. - The purpose of this memorandum is to describe the hydrologic and hydraulic criteria applicable to the design of the Littleville Dam and Reservoir on the Middle Branch of the Westfield River, Connecticut River basin. Part I - Hydrology, includes sections on climatology, stream flow, water supply and spillway and outlet design criteria. Part II - Hydraulic Design, includes the analysis and design of hydraulic structures.

PART I - HYDROLOGY

B. BASIN DESCRIPTION

2. Location. - Littleville Dam will be located in Hampshire and Hampden Counties, Massachusetts about 0.9 miles above the mouth of the Middle Branch of the Westfield River. The Middle Branch joins the main stem of the Westfield River about 2.5 miles above Huntington, Massachusetts. About 25.2 miles below this confluence, the Westfield River enters the Connecticut River at West Springfield and Agawam, Massachusetts. The Littleville Reservoir at spillway crest will extend about 3.7 miles upstream from the dam into the town of Chester, Massachusetts. The general location of the dam site is shown on Plate No. I-1.

3. Watershed. - The watershed of the Middle Branch above the Littleville dam site is long and narrow, having a length of 17.6 miles oriented in a north-northwest direction and a maximum width of 4.5 miles. The dam will control 52.3 of the total 53.0 square miles of the Middle Branch. The watershed has a single stream pattern with numerous short side tributaries emerging from steep narrow valleys. There is little natural storage in the channel and only an insignificant amount in the few small ponds scattered over the watershed. The slope of the main stream is about 70 feet per mile over its 16 miles of length. Elevations along the perimeter of the basin vary from above 1,000 to

over 2,200 feet above mean sea level (m.s.l.). A basin map and the main stream profile are shown on Plates No. I-2 and I-3, respectively.

C. CLIMATOLOGY

4. General. - The Westfield River basin has a variable climate. It frequently experiences periods of heavy precipitation produced by local thunderstorms and larger weather systems of tropical and extra-tropical origin. The basin lies in the path of prevailing "westerlies" which generally travel across the country in an easterly or northeasterly direction producing frequent weather changes. The temperature within the basin ranges from a summertime high in the nineties to sub-zero, occurring for short periods in the winter. In the upper regions, typified by the Middle Branch watershed, snow covers the ground from December until the spring melting season in late March to mid-April.

5. Temperature. - The mean annual temperature in the Westfield River basin varies from about 44°F in the mountainous regions to about 50°F in the valleys. Recorded temperature extremes at representative stations within or adjacent to the Westfield River watershed have varied from a maximum of 102°F in the lower watershed to a minimum of -30°F in the headwaters. Freezing temperatures may be expected from the latter part of October until late in April. Table I-I shows the mean, maximum and minimum monthly and annual temperatures at Westfield, Knightville Dam and West Cummington, Massachusetts in the basin, and at Pittsfield, Massachusetts, just west of the basin, but indicative of temperatures in the Middle Branch watershed.

6. Precipitation. - The average annual precipitation over the Westfield River basin is approximately 46 inches, uniformly distributed throughout the year. The maximum and minimum annual precipitation at Peru, Massachusetts are 65.42 inches in 1955 and 36.15 inches in 1941, respectively. Table I-II summarizes the monthly and annual precipitation at Peru, Knightville Dam, Chester and Westfield, Massachusetts.

7. Snow. - The mean monthly and annual snowfall at Knightville Dam, Chester, Chesterfield and Peru in Massachusetts are shown in Table I-III. The periods of record for the above stations vary from 12 to 23 years. Knightville Dam and Chester are considered representative of the lower basin, having elevations of 630 and 600 feet m.s.l., respectively, while Chesterfield, elevation 1,425 feet, m.s.l. and Peru, elevation 1,860 feet m.s.l., are typical of the headwater region. The locations of these stations are shown on Plate I-1.

TABLE I-I

MONTHLY TEMPERATURES
(Degrees Fahrenheit)

Month	Westfield, Mass. Elev. 220 ft., m.s.l. Period of Record-21 yrs			Knightville Dam, Mass. Elev. 630 ft., m.s.l. Period of Record-11 yrs			West Cummington, Mass. Elev. 1181 ft., m.s.l. Period of Record-12 yrs			Pittsfield, Mass. Elev. 1153 ft., m.s.l. Period of Record-40 yrs		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum
January	26.5	71	-16	23.7	60	-24	21.0	59	-29	21.1	65	-22
February	24.9	65	-27	26.2	63	-16	23.2	61	-30	21.8	63	-26
March	35.6	86	-11	32.6	69	-14	31.2	81	-22	30.8	80	-11
April	46.7	92	18	45.6	84	10	43.0	88	5	42.1	91	5
May	58.6	92	29	55.3	90	23	53.5	89	20	54.1	95	25
June	67.3	101	36	64.9	99	32	62.3	93	29	63.0	100	33
July	72.0	98	42	70.1	99	40	66.4	95	35	67.5	101	39
August	69.8	98	38	67.2	100	38	64.0	97	30	65.7	100	31
September	62.9	94	27	59.0	100	24	57.2	95	22	58.2	95	25
October	52.4	90	18	49.8	88	17	48.1	84	14	47.5	89	14
November	40.8	82	-2	38.0	81	2	37.3	78	1	37.0	76	-1
December	29.2	65	-16	27.7	61	-19	25.2	62	-24	25.0	67	-23
Annual	49.2	101	-27	46.7	100	-24	44.2	97	-30	44.5	101	-26

TABLE I-II

MONTHLY PRECIPITATION
(Depth in Inches)

	Westfield, Mass. Elev. 220 ft., m.s.l. Period of Record-53 yrs			Knightville Dam, Mass. Elev. 630 ft., m.s.l. Period of Record-19 yrs			Chester, Mass. Elev. 600 ft., m.s.l. Period of Record-44 yrs			Peru, Mass. Elev. 1860 ft., m.s.l. Period of Record-28 yrs		
Month	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum
January	3.19	7.52	0.77	3.15	6.40	0.75	3.53	6.83	0.91	3.79	7.31	1.00
February	3.38	6.75	1.24	2.75	4.67	1.24	3.16	5.18	1.69	3.20	6.58	1.27
March	3.87	9.71	0.27	4.00	10.18	1.28	3.91	10.49	0.21	4.55	10.32	1.25
April	4.10	8.72	0.75	3.69	5.73	0.82	3.83	8.37	0.75	3.83	6.43	1.17
May	3.90	7.08	1.03	3.99	6.73	0.95	3.93	7.77	1.15	4.43	7.77	1.75
June	4.02	8.73	0.39	3.21	6.23	0.57	4.11	9.15	0.23	4.41	10.55	1.53
July	3.85	10.06	1.27	3.80	7.33	1.12	3.99	8.49	1.01	4.50	10.88	1.73
August	4.29	26.85	0.71	3.41	15.27	1.15	3.99	18.44	0.50	3.97	14.07	0.78
September	4.05	12.41	0.24	3.57	8.06	1.38	3.94	12.61	0.40	4.79	12.36	0.68
October	3.55	12.50	0.05	3.65	16.95	1.19	3.65	17.51	0.00	3.69	14.37	0.76
November	4.15	9.79	0.40	4.53	7.18	0.81	4.37	11.01	1.00	4.22	8.35	1.13
December	3.71	7.50	0.60	3.80	6.21	0.65	3.59	9.19	0.76	4.02	10.37	1.14
Annual	46.38	70.33	33.35	43.92	62.26	32.15	45.90	67.50	32.23	49.86	65.42	36.15

8. Snow Cover. - Snow surveys have been taken in the Westfield River watershed above Knightville Dam since 1950. These surveys indicate that the water content of the snow normally reaches a maximum about the middle of March. The recorded mean, maximum and minimum average basin water content of the snow in March are: 3.2 inches, 7.8 inches, and less than 0.5 inches, respectively. Moderately high springtime discharges occur frequently as a result of melting snow but runoff from this source has been insufficient to cause a major flood. Heavy rain in conjunction with snowmelt runoff is a possibility about every year; however, the peak flow generally is of lesser magnitude than one resulting from an intense summer type storm. However, the volume of flood runoff resulting from snowmelt and concurrent rainfall would likely exceed the volume resulting from heavy rainfall alone.

9. Storms. - The Westfield River watershed has experienced storms of four general types namely:

a. Extra-tropical continental storms which move across the basin under the influence of the "prevailing westerlies".

b. Extra-tropical maritime storms which originate and move northward along the Eastern United States coast.

c. Storms of tropical origin some of which attain near hurricane magnitude.

d. Thunderstorms produced by local convective activity or by more general frontal activity.

The most severe storms have been of tropical origin which occur during the late summer and early autumn. The two largest floods in the Middle Branch, Westfield River occurred in September 1938 and August 1955 and were produced by storms of tropical origin.

D. RUNOFF

10. Discharge Records. - A U.S. Geological Survey gaging station has been operated continuously since July 1910 at Goss Heights on the Middle Branch of the Westfield River. This station is located 0.35 miles upstream of the mouth and about 0.5 miles downstream of the Littleville dam site. The mean daily discharges at this station for the period of record are shown on Plates No. I-6 thru I-10. Four additional gaging stations are currently maintained by the U.S. Geological Survey in the Westfield River basin. Records obtained from these stations indicate that the annual runoff values are comparable to the Goss Heights station.

TABLE I-III

MEAN MONTHLY SNOWFALL
(Average Depth in Inches)

Month	Knightville Dam, Mass. Elev. 630 ft., m.s.l. Period of Record-12 Yrs	Chester, Mass. Elev. 600 ft., m.s.l. Period of Record-20 Yrs	Chesterfield, Mass. Elev. 1425 ft., m.s.l. Period of Record-23 Yrs	Peru, Mass. Elev. 1860 ft., m.s.l. Period of Record-18 Yrs
January	12.00	13.34	15.83	15.28
February	12.55	14.14	17.52	15.92
March	13.47	10.16	13.72	16.84
April	4.63	1.92	4.84	6.10
May	0	0	0.15	0.20
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0
September	0	0	0	0
October	0	0	0.15	0.32
November	2.16	4.15	5.39	5.49
December	6.75	8.95	10.15	11.83
Annual	51.56	52.66	67.75	71.98

11. Stream Flow Data. - The average annual runoff for the period of record through September 1958 for the Middle Branch, Westfield River has varied from 42.29 inches in 1955 to 14.30 inches in 1941 with a mean of 27.05 inches. A summary of the mean, maximum and minimum monthly and annual runoff in inches for the period of record at Goss Heights is shown in Table I-IV. The most critical periods with respect to yield for water supply development occurred in the years 1914-15, 1930-31 and 1939-40.

TABLE I-IV

MONTHLY RUNOFF
(Inches)

	Middle Branch, Westfield River at Goss Heights, Massachusetts Drainage Area - 52.6 sq. mi.		
Month	Mean	Maximum	Minimum
January	2.19	4.67	0.33
February	1.76	4.70	0.35
March	4.91	14.13	1.31
April	5.94	12.59	1.80
May	2.94	6.00	0.89
June	1.44	4.52	0.27
July	0.68	2.78	0.11
August	0.67	6.93	0.10
September	0.82	6.96	0.03
October	1.17	11.12	0.10
November	2.10	7.71	0.26
December	2.35	5.74	0.39
Annual	27.05	42.29	14.30

E. HISTORY OF FLOODS

12. General. - Floods in the Middle Branch, Westfield River may result from intense rainfall over the basin or from rainfall in conjunction with melting snow. The Middle Branch is a precipitous mountain stream having a relatively minor amount of channel storage and a flashy runoff characteristic. Floods have occurred frequently in the Middle Branch, probably due to orographic influences of the watershed and the rapid runoff characteristics of the topography.

13. Floods of Record. - The maximum flood of record in the Middle Branch, Westfield River occurred on 21 September 1938 as a result of intense rainfall accompanying the hurricane which traveled up the Connecticut River valley. The second largest flood in the basin was produced by heavy rainfall associated with hurricane "Diane" in August 1955 which was preceded by substantial rainfall from hurricane "Connie" one week earlier. The third largest flood of record occurred on 31 December 1948 and was produced by intense rainfall falling upon frozen ground. Table I-V shows the peak discharge of recorded floods at Goss Heights, Massachusetts.

TABLE I-V

RECORDED FLOODS

MIDDLE BRANCH, WESTFIELD RIVER AT
GOSS HEIGHTS, MASSACHUSETTS
(1910-1959)
(Drainage Area 52.6 Sq. Mi.)

Date	Peak Discharge (c.f.s.)	CFS per Square Mile
21 September 1938	19,900	378
19 August 1955	16,500	314
31 December 1948	9,600	182
18 March 1936	8,400	160
26 November 1950	8,320	158
17 September 1933	8,020	153
15 October 1955	6,460	123
3 November 1927	5,860	112
9 January 1935	5,420	103
31 March 1951	5,020	96

14. Records indicate the occurrence of 15 historic floods in the Westfield River basin between 1776 and 1909. There is no reliable information as to the magnitude of these floods or to their contributing areas. The floods of October 1869 and December 1878 were reportedly severe and caused considerable damage.

F. WATER SUPPLY STORAGE CAPACITY

15. General. - The amount of storage to be provided for future water supply in the Littleville dual-purpose reservoir was contingent upon the stipulation prescribed by the city of Springfield, Massachusetts, that pursuant to the Water Supply Act of 1958, Title III, Public Law 85-500, its share of the cost be limited to 30 percent of the total project cost.

16. Cost allocation studies indicate that to satisfy the preceding criteria, the water supply storage will be limited to 9,400 acre-feet equivalent to 3.37 inches of runoff. The lowest intake will be elevation 447.0 and the maximum level will be controlled by a low weir at elevation 518.0 feet m.s.l. The water supply pool will fluctuate annually with a complete draw-down occurring only during an extreme dry period and a high rate of consumption. Discussion of the desires of the city of Springfield and the cost allocation studies is included in Design Memorandum No. II - General Design.

G. FLOOD CONTROL STORAGE CAPACITY

17. General. - In New England it is generally considered desirable to provide about eight inches of reservoir storage in order to obtain a reasonably high degree of flood protection at downstream damage areas. This criteria is based upon experience gained in operating flood control reservoirs in New England, particularly Knightville Dam on the Westfield River and by the severity of recent storms, notably September 1938, December 1948, and August and October 1955. The full storage capacity of 5.6 inches of runoff at Knightville Reservoir has been used twice within the 19-year period of regulation. History of storms and floods in New England has demonstrated that close succession of events requires adequate reserve storage for effective control.

18. Littleville Reservoir will contain 23,000 acre feet of flood control storage, equivalent to 8.2 inches of runoff from the 52.3 square miles of watershed. Regulation studies demonstrate that this storage capacity is adequate to control past floods of record. It also provides some margin for a flood on the Middle Branch that would have occurred in the past had the storm centers been shifted only about 10 miles.

H. UNIT HYDROGRAPH ANALYSIS

19. General. - Stream flow records from 1910 to date are available for the U.S. Geological Survey gaging station located at Goss Heights, Massachusetts approximately 0.5 miles downstream of the Littleville dam site. The flood discharge records for this station were analyzed to determine unit hydrographs for the watershed. Applicable precipitation records were taken from several stations within or adjacent to the basin.

3.37
8.2
11.57 $\frac{3.37}{11.57} = 29\%$

The following precipitation stations, shown on Plate No. I-1, having varying periods of record were used: Knightville Dam, Washington, Chester, Chesterfield, Middlefield, Worthington Center, Peru, Cummington, West Cummington, Dalton and Plainfield, Massachusetts.

20. Unit Hydrograph at U.S.G.S. Gage, Goss Heights. - Four flood periods were selected for unit hydrograph development from review of the stream flow and precipitation records. The selected storms include the major floods of September 1938 and August 1955 and two smaller floods all having periods of intense rainfall. Precipitation records for short duration rainfall over the Westfield River basin are unavailable for flood periods prior to 1939. Hourly precipitation is available from 1939 to date at Washington, and at Knightville Dam from 1942. There are no U.S. Weather Bureau first order stations within or immediately adjacent to the Middle Branch watershed. Plates No. I-11 thru I-19 show the derivation of unit hydrographs from the floods of 17-21 September 1938; 17-20 August 1955; 25, 26 November 1950 and 14-17 October 1955.

21. Adopted Unit Hydrograph. - The computed three-hour unit hydrograph developed from the September 1938 flood had a peak ordinate of 6,900 c.f.s., equivalent to 131 c.s.m. The peak of this unit hydrograph was increased to 8,000 c.f.s. to reflect the increased runoff rates anticipated during the probable maximum storm which has a rate of rainfall more than three times that of September 1938. The coefficients t_p, c_t and c_p 640 for the adopted three-hour unit hydrograph are 2.25 hours, 0.43 and 322, respectively, and are considered appropriate for the rugged mountainous topography. The adopted three-hour unit hydrograph, shown on Plate No. I-20, is considered applicable for deriving inflow hydrographs to a full reservoir as valley storage and change in lag time in the reservoir reach are negligible.

I. SPILLWAY DESIGN FLOOD

22. General. - The spillway design flood represents the most severe condition of runoff that would result from the probable maximum precipitation falling on ground saturated by previous rains. Concurrently it is assumed that Littleville Reservoir is filled to spillway crest as a result of previous runoff. It is further assumed that the outlet gates are operative and open during the passage of the flood.

23. Probable Maximum Precipitation. - Values of rainfall for the maximum probable storm were obtained from Hydrometeorological Report No. 33, "Seasonal Variation of the Probable Maximum Precipitation East of the 105th Meridian", dated April 1956, as prepared by the Hydrometeorological Section of the U.S. Weather Bureau. Losses from infiltration, surface detention, transpiration and other intangible

factors were assumed at a rate of 0.20 inches per three-hour period, which is consistent with minimum losses determined in previous studies for the New England area. Rates of precipitation, losses and rainfall excess as used in the selected storm pattern to compute the spillway design flood inflow, are shown in Table I-VI. The depth-duration curve of the probable maximum precipitation for the 52.3 square miles drainage area above Littleville Dam is shown on Plate No. I-21. The selected depth-duration relationship assumes a uniform hourly distribution of the maximum six-hour rainfall value. It is interesting to note that the probable maximum precipitation for 48 hours exceeds the "Diane" rainfall for 50 square miles by only 31 percent.

TABLE I-VI

PROBABLE MAXIMUM PRECIPITATION

Time in Hours	Rainfall in Inches	Losses in Inches	Rainfall Excess in Inches
0	0	0	0
3	0.1	0.1	0
6	0.1	0.1	0
9	0.3	0.2	0.1
12	0.3	0.2	0.1
15	0.6	0.2	0.4
18	0.9	0.2	0.7
21	9.45	0.2	9.25
24	9.45	0.2	9.25
27	1.8	0.2	1.6
30	0.8	0.2	0.6
33	0.5	0.2	0.3
36	0.3	0.2	0.1
39	0.2	0.2	0
42	0.1	0.1	0
45	0.1	0.1	0
48	0.1	0.1	0
Total	25.1	2.7	22.4

24. Spillway Design Flood Inflow. - The spillway design flood inflow hydrograph was derived by applying the rainfall excess of Table I-VI to the adopted three-hour unit hydrograph (Plate No. I-20). The peak of the spillway design flood inflow hydrograph is 98,000 c.f.s. which is about five times the flood of record (September 1938). An additional trial inflow hydrograph was derived by applying rainfall excess from a probable maximum storm assuming non-uniform distribution of the maximum six-hour value. This distribution with 2/3 of the maximum six-hour value in a three-hour period increased the peak to 113,000 c.f.s. This inflow hydrograph was considered excessive for spillway design purposes, but it was determined that the selected spillway would be adequate for this flood with a freeboard of 3 feet.

25. Spillway Design Flood Outflow. - The selected spillway design flood described in the above paragraph was routed through the surcharge storage using the reservoir capacity curve shown on Plate No. I-5. A spillway length of 400 feet is proposed. The outlet is assumed to be operable during the spillway design flood and the gates are assumed to be open. The flood routing shown on Plate No. I-22, resulted in a maximum pool stage of 591.0 feet, m.s.l. a surcharge depth of 15.0 feet and a peak outflow of 92,000 c.f.s. over the spillway. The outlet discharge at maximum pool stage is about 2,200 c.f.s. Had the gates been closed and inoperative, the pool would rise only an additional 0.2 of a foot.

26. Spillway Design Flood with Snowmelt. - The selected spillway design flood does not include runoff from snowmelt; however, consideration was given to the development of such a flood for the basin. A study of hydrologic records shows that, although a spring storm combined with snowmelt would produce a flood having a somewhat higher volume than the all-season storm, the flood peak would be lower. Littleville Reservoir will have a relatively small amount of surcharge storage, so that, high peak flow is a more severe criterion than flood volume. Furthermore, should a spring-type flood be developed for analysis, it is logical to assume that if heavy snow-cover was on the ground, there had been no antecedent runoff and the reservoir would be empty at the start of the spillway design flood. This additional storage would reduce the spillway design flood outflow and, therefore, the design requirements of the spillway.

J. TOP OF DAM ELEVATION

27. Freeboard. - The term "freeboard" as used in this memorandum refers to the difference in elevation between the maximum water surface elevation and the top of the earth embankment constituting the dam. The freeboard is provided to prevent water from going over the top of the dam by wind set-up or wave action when the reservoir is at maximum surcharge.

28. Wind and wave action includes the vertical wave height, wave ride-up and wind set-up. The procedure outlined in memorandum entitled "Conference on Determination of Freeboard Requirements for the McGee Bend Dam, Angelina River, Texas", dated 1 August 1956 was used to compute the freeboard. A maximum effective fetch of 0.73 miles and a wind velocity of 60 miles per hour over land, equivalent to 78 miles per hour over water, were used in the above computations. These assumptions resulted in a significant wave height of 3.05 feet, wind set-up of .05 feet and wave relative run-up ratio of 1.0. The total computed freeboard is 3.1 feet; however, since this computed value is less than the prescribed minimum standard, a freeboard of five feet for the earth embankment was adopted.

29. Selected Elevation, Top of Dam. - The top elevation of the Littleville Dam was determined from the following data:

Elevation of Spillway Crest	576.0 feet, m.s.l.
Maximum Spillway Surcharge	15.0 feet
Minimum Freeboard	5.0 feet
Top of Dam Elevation	596.0 feet, m.s.l.

K. WATER SUPPLY

30. Requirements. - After authorization of Littleville Dam and Reservoir, the city of Springfield, Massachusetts, submitted a request for incorporation of water supply storage in the reservoir plan. Need for additional water supply is demonstrated by the curve "Trend in Average Daily Water Consumption from Little River Supply, 1910 - 1980" submitted by representatives of the city and shown on Plate No. I-25. This curve shows that the ultimate yield of the present source, 55 m.g.d., is expected to be fully utilized by the year 1980. The city desires to develop a supplemental source of water which will provide a dependable yield of 17.5 m.g.d. However, participation in the Littleville project will be limited by the city's stipulation that its share of the cost be 30 percent of the total cost of the project as provided in Public Law 85-500 Title III, Water Supply. As the result of cost allocation, determined by the joint use of facilities method, (see General Design Memorandum, No. II), the city will have 9,400 acre-feet of storage available for water supply development in the Littleville Reservoir. Several industrial plants are located on the Westfield River below the West Branch which use varying amounts of the normal flow in the river for hydropower and for process purposes.

31. Runoff Data. - Hydrologic studies were made in order to determine the dependability and yield of flow in the Middle Branch and in the main stem of the Westfield River. Since all runoff stored or diverted into the water supply system at the Littleville project will

9400 AF - 3,37"

3.37 = 8970

11.57

affect natural flow in the Westfield River, the Water Resources Commission, Commonwealth of Massachusetts has been requested to determine and prescribe the minimum flow in the Westfield River and Middle Branch, below which there should be no diversion of flow for water supply purposes. Natural flow-duration curves for the Middle Branch at Goss Heights and the Westfield River at Huntington are shown on Plate No. I-25. The Westfield River curve is a composite developed from runoff data for U. S. Geological Survey gaging stations on the Westfield River at Knightville, Middle Branch at Goss Heights and the West Branch at Huntington.

32. Dependability of Yield. - Records from the gaging station at Goss Heights show that the water supply storage of 9,400 acre-feet in Littleville Reservoir can be filled every year from normal spring runoff. The water years 1914-15, 1930-31 and 1939-40 were found to be the most critical periods for water supply development on the Middle Branch. A curve of percent dependability of yield for water supply for various minimum low flow reservations and water supply storage of 9,400 acre-feet in Littleville Reservoir is shown on Plate No. I-25. Pending the Commission's requirements for low flow, estimates of dependable yield were made assuming no diversion of flows whenever natural discharges on the Middle Branch drop to various rates between 0.1 and 0.6 c.s.m. With this assumption, the Middle Branch will yield from 14 to 18 m.g.d. with a water supply storage of 9,400 acre-feet, and have a statistical dependability of about 98 percent.

33. The statistical dependability of yield was determined from analyzing 48 years of discharge records from the Goss Heights gage. The maximum supplemental storage requirement for each annual deficiency period, assuming various rates of continuous water supply demand, was determined from the mass diagram of mean monthly runoff in inches. Curves of yield vrs. storage requirement with frequency as a parameter were drawn through points determined from the storage values arranged in order of magnitude and assigned Beard's frequency plot positions. The dependability of yield vrs. low flow reservation curves were developed for a water supply storage allocation of 9,400 acre-feet and assuming various rates of low flow reservation.

34. Water Supply Conduit. - A 4-foot diameter conduit, selected by the city of Springfield, will be provided for water supply with the invert at elevation 432.0 feet m.s.l. This conduit will be constructed within a 9-foot wide arch-shaped concrete conduit which will be used for stream diversion during construction. Initially about 800 feet of the water supply conduit will be placed. Later, probably within 10-20 years, when the permanent pool is put into use for water supply, a low-flow valve will be provided on the water supply conduit at the downstream toe of the dam to release low flows into the Middle Branch. Details of the water supply system are described in Design Memorandum No. II, General, and are shown on Plate No. II-8 of the memorandum.

35. Stream Diversion During Construction. - The permanent construction will be protected by a cofferdam and stream diversion structure during the second construction season. A ten-year frequency flood, developed for the construction season, has a peak discharge of 7,300 c.f.s., equivalent to about 140 c.s.m., and a runoff volume of 3.5 inches. Diversion will be made through a 9-foot wide arch-shaped concrete conduit approximately 800 feet in length with entrance invert at elevation 432.0 feet m.s.l. This structure, with a 4-foot diameter water supply conduit supported on saddles within it, will have hydraulic characteristics similar to an 8-foot diameter circular section. Routing of the 10-year construction flood through the reservoir storage, assuming the pool initially empty, resulted in a maximum pool level of 501.5 feet m.s.l. At this stage impoundment would be about 5,800 acre-feet, equivalent to 2.1 inches over the 52.3 square mile drainage area. Top grade of the cofferdam will be elevation 503.0 feet m.s.l.

L. FLOOD CONTROL OUTLET CAPACITY

36. General. - The capacity of the outlet must be adequate (a) to pass the normal flow of the stream and the safe channel capacity without imposing restrictions on the right of riparian owners below the dam and without using more than a minor portion of the storage capacity of the reservoir; (b) to pass discharges required for regulation of the reservoir during floods; (c) to permit drainage of the flood control storage within a reasonable period of time. As described in the following paragraphs, an eight-foot diameter, horse-shoe-shaped conduit with two 4' x 8' gates, was found to satisfy the above criteria and was adopted. Design Memorandum No. II, General Design, includes a discussion on the reasons leading to a flood control outlet separate from the water supply conduit.

37. Channel Capacity. - The channel capacity of the Middle Branch below the dam is estimated to be between 2,000 and 3,000 c.f.s. However, the maximum regulated release will be limited to between 1,000 to 1,500 c.f.s. due to the flow from the residual uncontrolled drainage area and the downstream channel capacity of the Westifield River. The conduit and gates will be adequate to maintain the maximum safe channel capacity with a pool at an elevation that represents about 15 percent of the flood control storage. The maximum discharge will be about 2,200 c.f.s. with pool at spillway crest.

38. Outlet Discharge During Floods. - The Littleville Reservoir will be regulated in conjunction with Knightville Reservoir on the Westfield River to control flood flows on the Westfield River. In addition, the reservoir will be operated in conjunction with other reservoirs in the Connecticut River basin, for regulation of flood flows in the lower Connecticut River. Principal damage centers are:

Huntington, Russell, Woronoco, Westfield and Agawam on the Westfield River; West Springfield at the junction of the Westfield River; and Springfield, Hartford, and East Hartford on the Connecticut River. The discharge through the flood control outlet works will be regulated in accordance with river stages at index points downstream of the dam.

39. Time of Emptying. - The time required to evacuate the flood control pool of Littleville Reservoir would be about nine days, assuming a discharge of 1,500 c.f.s. and an inflow of 150 c.f.s. During the emptying period the regulated outflow from Littleville Reservoir would be coordinated with the outflow from Knightville Reservoir and generally will be based upon the flood control storage available in the respective reservoirs.

40. Tailwater Rating Curve. - Tailwater conditions at Littleville Dam will approximate those at the U.S. Geological Survey Gaging Station about 0.5 miles downstream of the dam site. The discharge rating curve shown on Plate No. I-23 was computed from high water marks and relationship to the downstream gaging station.

M. EFFECT OF RESERVOIR REGULATION

41. General. - The proposed regulation of the Littleville Reservoir as described in paragraph 38 will be for the protection of the communities and damage areas downstream of the dam. The method of regulation was tested on the two major floods of record and the standard project flood, and is described in detail in the following paragraphs. The storm isohyetals and mass curves for the floods of record are shown on Plate No. I-24.

42. Flood of September 1938. - The maximum flood of record in the Middle Branch occurred on 21 September 1938 when a hurricane passed up the Connecticut River valley. Rainfall over the basin accompanying this hurricane combined with the precipitation of the previous three days totaled more than 10 inches. Regulation of Littleville Reservoir would have been initiated by closure of the gates about 6:00 a.m. on 20 September, when downstream river flows began to exceed the safe channel capacity. The reservoir would have stored about 11,100 acre-feet of flood water equivalent to 6.1 inches over the drainage area. The pool would have attained an elevation of 563.5 feet m.s.l. on 25 September when evacuation commenced. Had the maximum release rate been 1,200 c.f.s. the reservoir would have been empty in about seven days. The regulation of the reservoir in conjunction with Knightville is shown graphically on Plate No. I-26.

43. Flood of August 1955. - During the storm period, 17-22 August, rainfall over the Middle Branch watershed totaled more than seven inches. The flood control gates would have been closed about noon the 18th, when

the river flow began to exceed the safe channel capacity. The reservoir would have stored 14,600 acre feet of runoff equivalent to about 5.2 inches and attained an elevation of 558.0 feet m.s.l. Evacuation of the pool would have commenced about midnight August 20th and would have been complete in about seven days, assuming a maximum release rate of 1,200 c.f.s. The regulation is shown graphically on Plate No. I-26

44. Standard Project Flood. - In many areas of southern New England the August 1955 storm and flood exceeded all previous events. Plate Nos. I-21 and I-24 show the depth-duration and area-depth relationships of the standard project storm to record storms over the northeastern United States. A standard project flood was developed for the Westfield River basin from standard project storm rainfall, as described in Civil Engineer Bulletin No. 52-8 and unit-hydrographs derived from analyzing record floods in the basin. The flood was developed for a design criterion for the local protection project at Westfield, Massachusetts, hence the storm center was located downstream of Knightville and Littleville Reservoirs in order to measure the runoff potential from the residual uncontrolled watershed. The 24-hour storm volume averaged 8.80 inches and infiltration and other losses were assumed at a rate of 0.07 inches per hour yielding a rainfall excess volume at 7.40 inches. The standard project flood, at the Westfield U.S. Geological Survey gage, had a maximum discharge of 180,000 c.f.s., which is about 122 percent greater than the record flood of August 1955.

45. The effect of the Littleville Reservoir in conjunction with the existing Knightville Reservoir on the standard project flood is shown on Plate I-27. Littleville Reservoir will have sufficient capacity to store, without utilizing surcharge, the standard project flood runoff from the Middle Branch, but spillway discharge would occur at Knightville on the recession side of the hydrograph. The total stage reduction at Westfield gage attributable to Littleville Reservoir would be 5.5 feet.

46. A standard project storm centered over the Middle Branch would produce rainfall totalling 10.60 inches in 24 hours, and a rainfall excess of about 9.00 inches. Assuming the water-supply storage initially full, this flood would fill the reservoir and produce spillway discharge to a depth of 1.1 feet.

47. Frequency of Filling. - The frequency of filling curve shown on Plate I-28 was developed considering only the use of the flood control storage above a pool level of 518 feet m.s.l., the level of the future water supply pool. During the initial 10-20 years of operation, a pool will be maintained at this level for recreation purposes; therefore, the guide curve for relocations, acquisition of land and flowage easements shows the frequency of flood control pool levels above

elevation 518 ft. m.s.l. Use of the project for water supply may change slightly the elevation-frequency relationship, but as floods in New England can occur in any month of the year, seasonal drawdown of the water supply pool will have little effect on the annual maximum pool elevation.

PART II - HYDRAULIC DESIGN

N. SPILLWAY

48. General. - The natural topography at the damsite together with the favorable rock formation in the left abutment led to the selection of a chute spillway. The spillway structure will consist of a curved low ogee weir and a discharge channel excavated in rock. Details of the spillway and discharge channel are discussed in the following paragraphs and are shown on Plate Nos. I-4 and I-31.

49. Length of Crest and Maximum Surcharge. - The spillway design flood, described in paragraphs 22-24, was routed through the surcharge storage, with the flood control gates operative, and assuming various spillway lengths. It was concluded from economic studies that a crest length of 400 feet and a corresponding maximum surcharge of 15 feet would be the most practical combination. With a spillway discharge of 92,000 c.f.s. and the crest at elevation 576.0 feet m.s.l., the maximum surcharge elevation will be 591.0.

50. Spillway Approach. - The higher ground upstream of the spillway crest will be excavated to elevation 569.0 providing a minimum approach depth of seven feet below the crest. This will create a shelf in front of the spillway extending upstream a maximum distance of 170 feet and averaging about 50 feet normal to the crest. Computations show that the maximum average approach velocity will be about 10 feet per second.

51. Discharge Coefficient. - In order to effect maximum economy and to improve the discharge efficiency, the spillway weir was designed for a head on the crest of 12 feet, which is 80 percent of the maximum surcharge depth. Discharge over the weir will not be affected by submergence or apron interference. The discharge coefficient curve shown on Plate No. I-29 was derived from Hydraulic Design Chart 122-1 in the data-book of Hydraulic Design Criteria.

52. Spillway Rating Curve. - The discharge rating curve shown on Plate No. I-29 was computed by using discharge coefficients described in the previous paragraph in the conventional weir formula. Friction loss in the short approach channel was negligible.

53. Crest Shape. - The shape of the low ogee crest was determined from data provided in Figure 1 and Table 1 of the Engineering Manual for Civil Works Construction, Part CXVI, Hydraulic Design, Spillways. A design head of 12 feet, 80 percent of the expected maximum head, was used in the formula $x^{1.85} = 2H_d^{0.85}$ to determine the shape of the weir below the crest. An apron curve with a radius of 16.8 feet is provided at the toe of the weir. A typical section of the spillway weir is shown on Plate No. I-30.

O. SPILLWAY CHUTE

54. General. - The spillway chute shown on Plate No. I-31 was found to be the most economical plan which would satisfy the hydraulic requirements. It is the result of a number of trials involving variations of channel cross section and invert slope. The analyses were made assuming a spillway discharge of 92,000 c.f.s. and a concurrent outlet discharge of 2,000 c.f.s. Hydraulic computations were made to determine velocities and water surface elevations, starting from the spillway apron.

55. Design of Chute. - The location of the spillway chute on the hillside and the quantity of rock which can be economically used in the construction of the dam tend to lessen the importance of minimum freeboard as a factor in the chute design. The selected chute bottom width converges from 373 feet, along the arc at the toe of the weir (station 1+18) to a minimum of 50 feet at station 6+87. The discharge channel has a 50 foot bottom width between stations 6+87 and 9+50, then reduces, through a transition section between stations 9+50 and 10+10, to a 20 foot bottom width extending to about station 13+50 where the flow returns to the river. The low point in the rock profile along the right bank occurs near station 7+50 where slight overtopping may result during the spillway design flood. However, due to the high velocity of flow in the direction of the chute the amount of water leaving the chute should be small, and neither the dam nor appurtenances should be endangered. In view of the infrequent occurrence of floods of spillway design magnitude the minimum freeboard in this area is considered sufficient. The slope of the chute invert varies to satisfy the slope of the rock topography and to insure supercritical flow for the cross-sectional area. Exposed ledge rock at the end of the chute obviates the need of a stilling basin.

56. Water Surface Profile. - The starting elevation for the drop-down computations beginning at station 1+18 on the spillway apron, was determined by the specific energy equation assuming the friction and other losses at the weir equal to 10 percent of the total available energy head on the spillway crest. From this starting point computations of water surface, velocity, and energy gradient were made in the spillway chute at sections ranging from 16 to 59 feet apart assuming a

roughness coefficient of 0.035. Convergence head losses, due to impact and turbulence, were assumed to be 10 percent of the difference in velocity head at the sections. The velocity accelerates from about 25 feet per second at the spillway apron to about 40 feet per second at the intersection with the outlet discharge channel and further accelerates to about 80 feet per second at the transition to the pilot channel. The velocity will decelerate from station 9+50 to station 13+50, where the slope flattens as it approaches the river channel. The tailwater will be about 21 feet deep during the maximum discharge of the spillway design flood.

P. FLOOD CONTROL OUTLET

57. Design Criteria. - A plan and profile of the outlet works is shown on Plate No. I-32. Studies indicate that the criteria set forth in paragraphs 36-38 will be satisfied with an outlet having a discharge capacity of about 1,000 c.f.s. with the pool at elevation 529 which is equivalent to about 15 percent of the total flood control storage. To insure that the one gate will provide adequate discharge capacity in the event that the other gate became inoperative, the combined area of the gates will exceed the conduit area by about 20 percent. Stream diversion during construction will be made through the water supply conduit as described in paragraph 35.

58. Outlet and Gates. - A horseshoe-shaped conduit, with a diameter of 8 feet satisfies the discharge requirements. The total cross-sectional area of the two 4' x 8' sluice gates is 64.0 square feet or 21 percent larger than the 43.1 square foot area of the conduit. The discharge capacity of one gate, with the pool at spillway crest, is 78 percent of the maximum discharge with both gates open.

59. Control Weir and Approach Channel. - A low ogee concrete weir, 30 feet in length and located in the outlet approach channel, will control the level of the permanent pool level during the normal range of flow. During high flows the conduit gates will be operated as required for maximum downstream benefit. The crest of the weir will be elevation 518.0 feet m.s.l., the level of the future water supply pool. The ogee section of the weir will be shaped to conform with the theoretical lower nappe profile given by the formula $x^{1.85} = 2H_d^{0.85}$, where H_d the design head is equal to three feet, the maximum head on the weir before the control shifts to the outlet works. The minimum approach depth will be three feet below the weir crest and will occur at the upstream face of the weir. The approach channel will be about 250 feet long and have a bottom width of 20 feet. Maximum head losses in the approach channel will be about 0.5 feet for a discharge of 500 c.f.s, the maximum weir-controlled flow.

60. <u>Invert Elevations of Conduit</u>. - From the toe of the control weir to the beginning of the horseshoe-shaped conduit (station 4+11) the invert will be level at elevation 513.0 feet m.s.l. From station 4+11 to 5+51.75, the conduit will have a slope of 0.35 percent. Through the transitions and gate passageways, the invert will be level at elevation 512.5. From station 6+17.75 at the lower end of the converging transition to station 7+62 at the portal, the conduit invert will have a slope of 0.35 percent. The elevation at the portal will be 512.0. Beyond the portal a paved apron, with a radius of 75 feet, will extend to station 7+80. From station 7+80 to 9+21.85 the invert will have a slope of 16 percent and will intersect the right side of the spillway chute at center line station 6+87, elevation 486.5 feet m.s.l.

61. <u>Intake</u>. - The walls of the approach channel will suppress the flow and thus eliminate the need for eliptical side curves in the conduit entrance. The intake section, between stations 3+88 and 4+11, will be combined with the transition section which varies from nearly square to horseshoe shape in the conduit. The intake roof will be ellipically shaped and conform to the equation $x^2/d^2+y^2/(2d/3)^2= 1$, where d is equal to 8 feet, the vertical dimension of the conduit. The side walls will converge at a rate of 1 foot in 8 feet from station 3+35.5 to 4+02. From station 4+02 to station 4+11, the beginning of the conduit, the side walls will be curved and have a radius of 75 feet. Details of the intake section are shown on Plate No. I-33.

62. <u>Trash Structure</u>. - A trash structure will be provided for the intake in accordance with the Engineering Manual for Civil Works construction Part CXXIV, Chapter 3, paragraph 3-05. The average velocity through the clear area of the trash structure will vary from about 7 to 12 feet per second. The maximum velocity occurs with a discharge of 2,440 c.f.s. and the pool at elevation 591.0 feet m.s.l., the maximum surcharge level.

63. <u>Gate Passageway Transitions</u>. - Details of the proposed gate passageway transitions are shown on Plate No. I-33. The combined length of the gate passage and divergent and convergent transitions will be 66 feet. Each transition section will be 20 feet long and both divergent and convergent side-wall slopes will be 15 to 1. The area of the gate passageway will be maintained approximately equal to the gate area, thereby, making the hydraulic control occur near the end of the pier during one gate operation. No vertical transition was required, since the gates and conduit will both be eight feet in height.

64. <u>Air Vent</u>. - Computations following procedures described in the Engineering Manual for Civil Works Construction, Part CXVI, Chapter 2, Hydraulic Design of Reservoir Outlet Structures, indicate that with the pool at elevation 591.0 feet m.s.l. (maximum surcharge), the maximum

air demand per gate would be about 210 c.f.s. Assuming a maximum velocity of 150 feet per second, the air vent will require a cross-sectional area of 1.4 square feet per gate. The air vents to the individual gates will be shaped to prevent cavitation and will be combined in a common riser having a cross-sectional area of 3.1 square feet. The entrance to the air vent will be located in the freeboard range above maximum surcharge elevation. To prevent backflow of water from one gate passage under pressure to the other flowing partly full, thereby cutting off the air supply to the latter, the junction of the individual gate air vents with the riser will be set at elevation 525.5 feet m.s.l., 5 feet above the roof of the gate passage and above the maximum pressure gradient. Friction and other losses in the air vent system were estimated to be about equivalent to one foot of water.

65. Conduit Characteristics. - Hydraulic elements of the 8-foot diameter horseshoe-shaped conduit are shown on Plate No. I-32. The illustrated characteristics include half section, area, hydraulic radius, velocities and discharges at normal and critical depths. The velocity and discharge at normal depths were based on a roughness coefficient of 0.014 and an invert slope of 0.35 percent.

66. Outlet Rating Curves. - The outlet rating curves shown on Plate No. I-32 include the discharge rating of the control weir which is the primary hydraulic control up to stages of about 2.5 and 3 feet for one and two gate operation, respectively. With the conduit flowing partly full, the control will be at the downstream end of the pier in the gate passageway. With one gate open and high reservoir stages, the control will be at the end of the pier, but with both gates open, the control will shift to the conduit portal.

67. Analysis of Flow Conditions. - Pressure and energy gradient profiles for two conditions of flow; namely, the normal regulated discharge and maximum capacity of the conduit with both gates fully open, are shown on Plate No. I-34. The minimum reservoir pool level sufficient to produce a regulated release of 1,000 c.f.s. with both gates fully open will be elevation 529 feet m.s.l. With the reservoir pool at spillway crest and both gates fully open the conduit will discharge 2,175 c.f.s. For structural design the greatest pressure in the conduit, downstream of the gates, will exist with the gradient at elevation 529 and a discharge of 2,200 c.f.s. Upstream of the gates the greatest pressure will occur when both gates are closed and the water surface is at the maximum surcharge elevation 591.0 feet m.s.l.

68. Outlet Stilling Basin. - Preliminary geologic investigations indicate that the bedrock at the outlet portal will be capable of withstanding the maximum velocity, 41 feet per second with the pool at

spillway crest. Therefore, no provisions for a conventional outlet stilling basin are considered necessary. However, concrete apron 18 feet long and widening to 12.5 feet will be constructed below the outlet portal. Below the apron an outlet channel will be excavated in rock on a slope of 16 percent, terminating in the spillway channel at centerline station 6+87.

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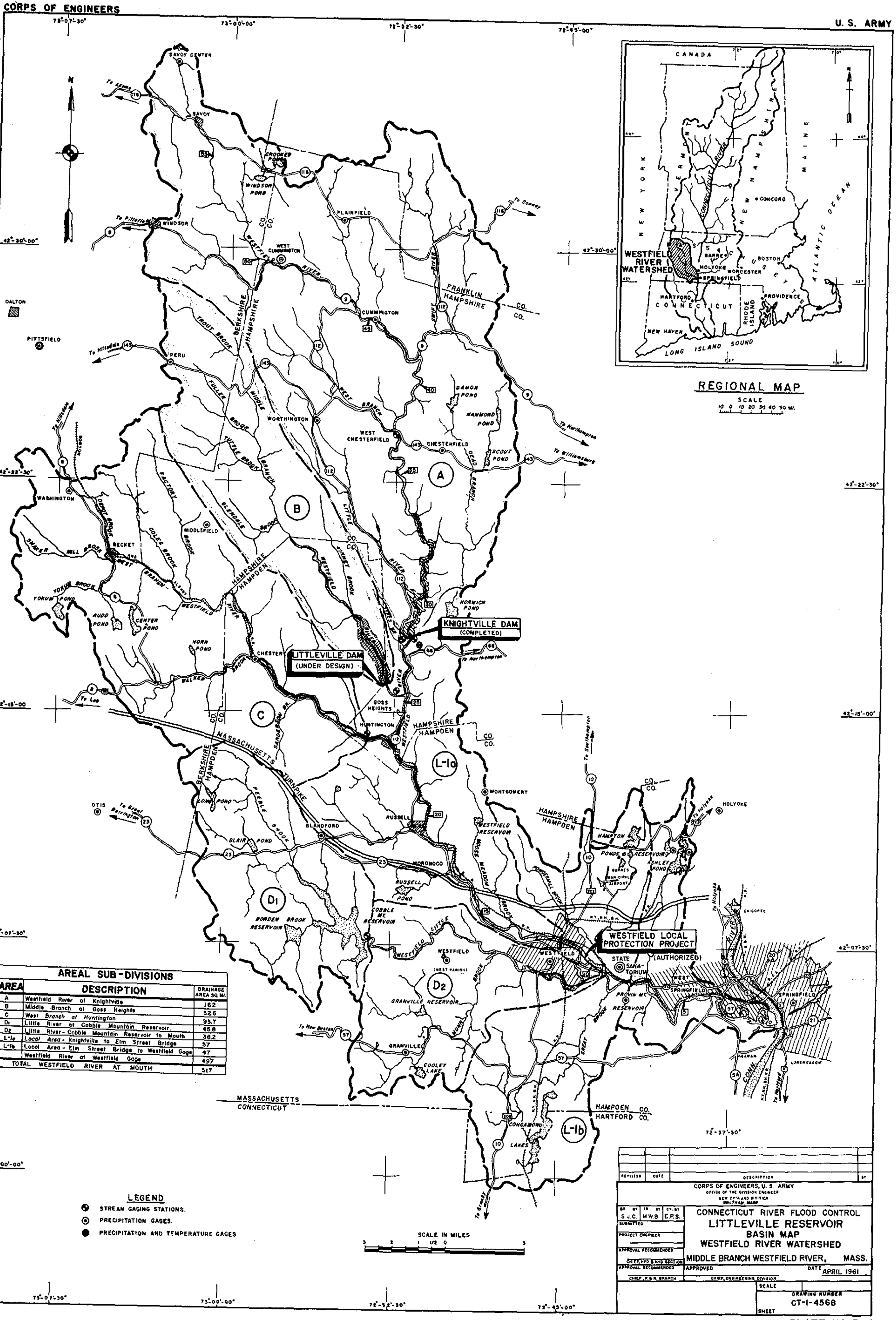


AREAL SUB-DIVISIONS

AREA	DESCRIPTION	DRAINAGE AREA SQ. MI.
A	Westfield River at Knightville	162
B	Middle Branch at Goss Heights	52.6
C	West Branch at Huntington	93.7
D1	Little River at Cobble Mountain Reservoir.	45.8
D2	Little River - Cobble Mountain Reservoir to Mouth	38.2
L-1a	Local Area - Knightville to Elm Street Bridge	57
L-1b	Local Area - Elm Street Bridge to Westfield Gage	47
	Westfield River at Westfield Gage	497
TOTAL WESTFIELD RIVER AT MOUTH		517

REVISION	DATE	DESCRIPTION	BY

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
WALTHAM, MASS

DR. BY	TR. BY	CK. BY
S.J.C.	M.W.B.	E.P.S.

SUBMITTED

PROJECT ENGINEER

APPROVAL RECOMMENDED

CHIEF, HYD & HYD. SECTION

APPROVAL RECOMMENDED

CHIEF, P. & R. BRANCH

CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE RESERVOIR
BASIN MAP
WESTFIELD RIVER WATERSHED
MIDDLE BRANCH WESTFIELD RIVER, MASS.

APPROVED

CHIEF, ENGINEERING DIVISION

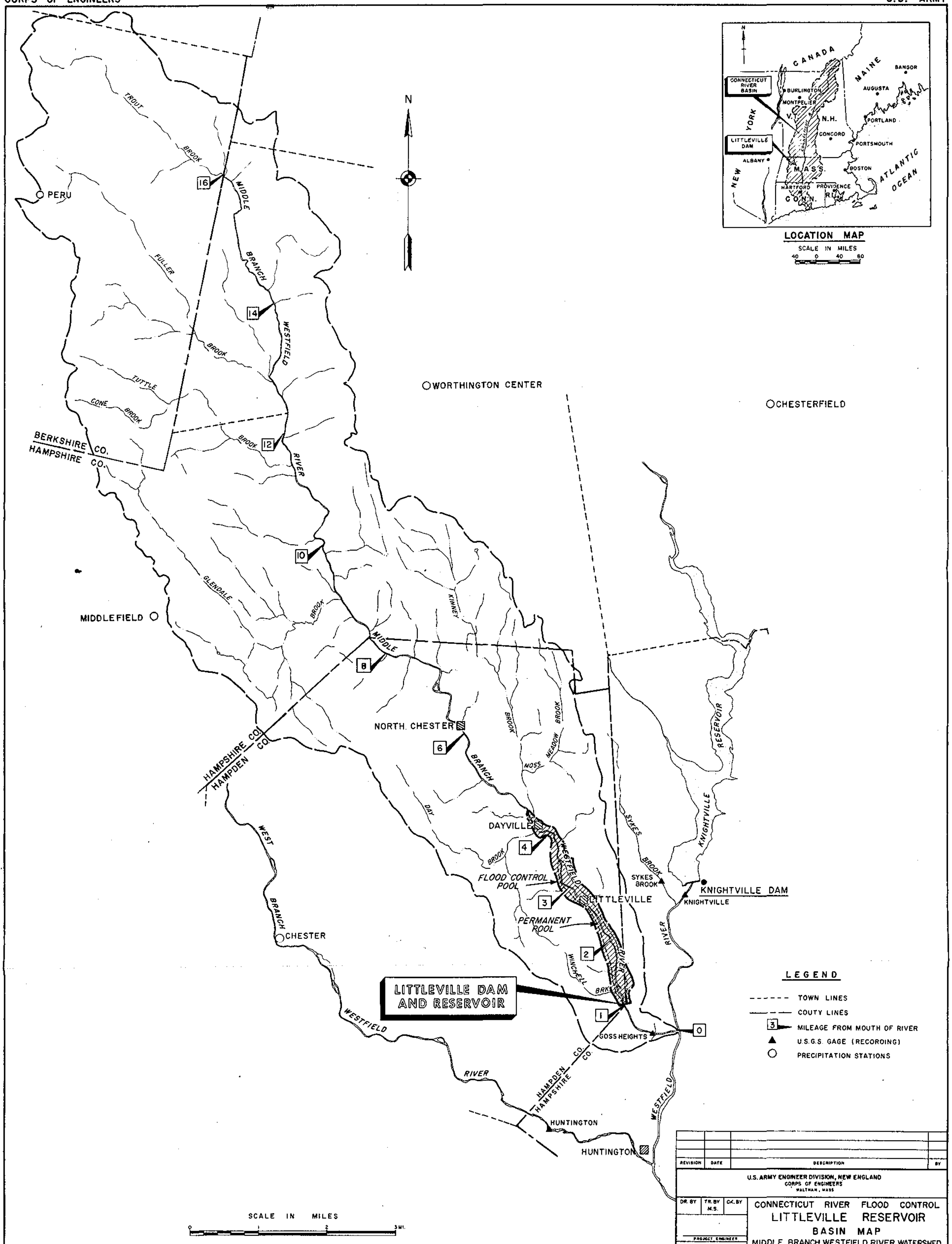
DATE APRIL 1961

SCALE

DRAWING NUMBER
CT-1-4568

SHEET

PLATE NO. I - I


N
PERU
TROUT BROOK
MIDDLE BRANCH WESTFIELD RIVER
FULLER BROOK
TUTTLE BROOK
CONE BROOK
BERKSHIRE CO.
HAMPSHIRE CO.
GLENDALE BROOK
KINNEY BROOK
WORTHINGTON CENTER
CHESTERFIELD
MIDDLEFIELD
NORTH CHESTER
MEADOW BROOK
MOSS BROOK
DAY BROOK
DAYVILLE
FLOOD CONTROL POOL
PERMANENT POOL
LITTLEVILLE
WINCHELL BRK
SYKES BROOK
KNIGHTVILLE RESERVOIR
KNIGHTVILLE DAM
KNIGHTVILLE
RIVER
HAMPSHIRE CO.
HAMPDEN CO.
WEST BRANCH
CHESTER
LITTLEVILLE DAM AND RESERVOIR
WESTFIELD RIVER
GOSS HEIGHTS
HUNTINGTON
16
14
12
10
8
6
4
3
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0
CANADA
MAINE
BANGOR
AUGUSTA
CONNECTICUT RIVER BASIN
BURLINGTON
MONTPELIER
VT.
N.H.
NEW YORK
PORTLAND
CONCORD
PORTSMOUTH
LITTLEVILLE DAM
ALBANY
MASS.
BOSTON
ATLANTIC OCEAN
HARTFORD
PROVIDENCE
CONN.
R.I.
LOCATION MAP
SCALE IN MILES
40 0 40 80
LEGEND
TOWN LINES
COUTY LINES
MILEAGE FROM MOUTH OF RIVER
U.S.G.S. GAGE (RECORDING)
PRECIPITATION STATIONS
SCALE IN MILES
0 1 2 3 MI.
REVISION DATE DESCRIPTION BY
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
DR. BY TR. BY M.S. CK. BY
CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE RESERVOIR
BASIN MAP
MIDDLE BRANCH WESTFIELD RIVER WATERSHED
MIDDLE BRANCH WESTFIELD RIVER, MASS.
PROJECT ENGINEER
CHIEF HYDR. HYD. SECTION
APPROVED:
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DATE: APRIL 1961
CHIEF ENGINEERING DIVISION
SCALE:
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PLATE NO. I-2

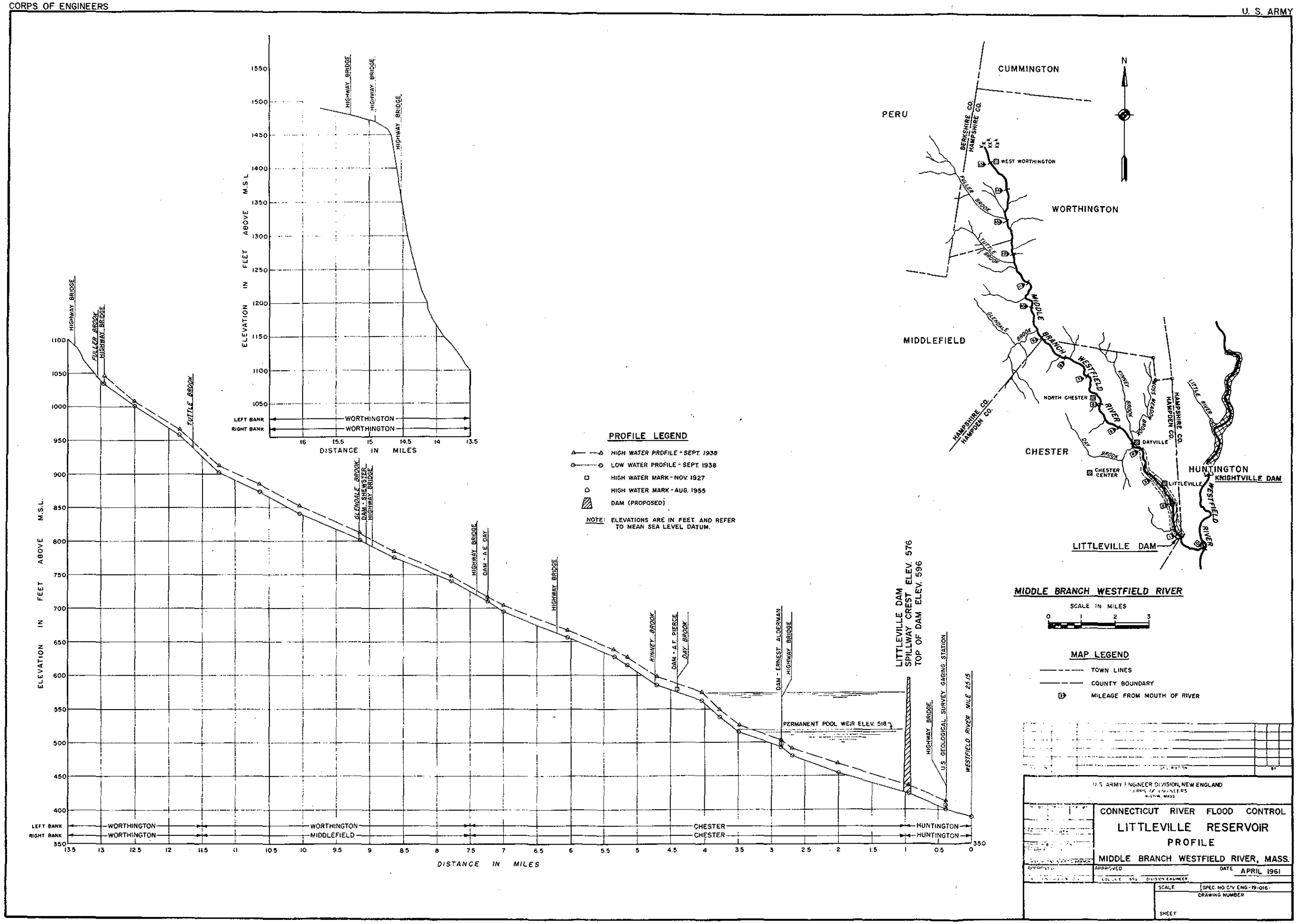
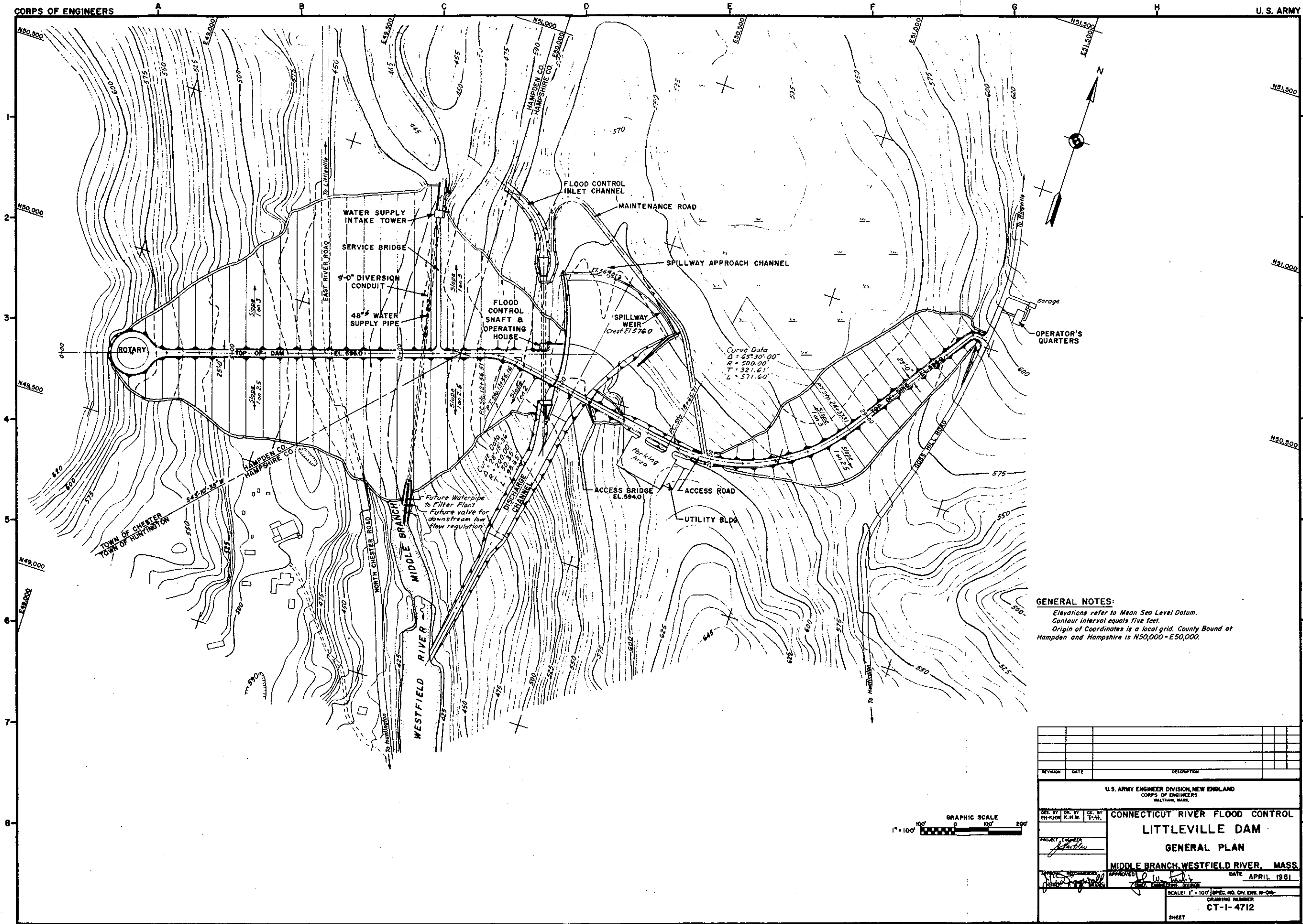

HIGHWAY BRIDGE
FULLER BROOK
HIGHWAY BRIDGE
TUTTLE BROOK
GLENDALE BROOK
DAM - SHEWSTER
HIGHWAY BRIDGE
HIGHWAY BRIDGE
DAM - A.E. DAY
HIGHWAY BRIDGE
KINNEY BROOK
DAM - A.F. PIERCE
DAY BROOK
DAM - ERNEST ALDERMAN
HIGHWAY BRIDGE
LITTLEVILLE DAM
SPILLWAY CREST ELEV. 576
TOP OF DAM ELEV. 596
PERMANENT POOL WEIR ELEV. 518
HIGHWAY BRIDGE
U.S. GEOLOGICAL SURVEY GAGING STATION
WESTFIELD RIVER MILE 25.15
ELEVATION IN FEET ABOVE M.S.L.
DISTANCE IN MILES
LEFT BANK
RIGHT BANK
WORTHINGTON
MIDDLEFIELD
CHESTER
HUNTINGTON
PROFILE LEGEND
HIGH WATER PROFILE - SEPT. 1938
LOW WATER PROFILE - SEPT. 1938
HIGH WATER MARK - NOV. 1927
HIGH WATER MARK - AUG. 1955
DAM (PROPOSED)
NOTE: ELEVATIONS ARE IN FEET AND REFER TO MEAN SEA LEVEL DATUM.
CUMMINGTON
PERU
BERKSHIRE CO.
HAMPSHIRE CO.
WEST WORTHINGTON
WORTHINGTON
FULLER BROOK
TUTTLE BROOK
MIDDLE BRANCH WESTFIELD RIVER
GLENDALE BROOK
MIDDLEFIELD
NORTH CHESTER
KINNEY BROOK
MOSS MEADOW BROOK
HAMPSHIRE CO.
HAMPDEN CO.
DAYVILLE
CHESTER
DAY BROOK
CHESTER CENTER
LITTLEVILLE
HUNTINGTON
KNIGHTVILLE DAM
LITTLE RIVER
WESTFIELD RIVER
LITTLEVILLE DAM
MIDDLE BRANCH WESTFIELD RIVER
SCALE IN MILES
MAP LEGEND
TOWN LINES
COUNTY BOUNDARY
MILEAGE FROM MOUTH OF RIVER
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE RESERVOIR
PROFILE
MIDDLE BRANCH WESTFIELD RIVER, MASS.
APPROVED
DIVISION ENGINEER
DATE APRIL 1961
SCALE
SPEC. NO. CIV. ENG.-19-016-
DRAWING NUMBER
SHEET

PLATE NO. I-3



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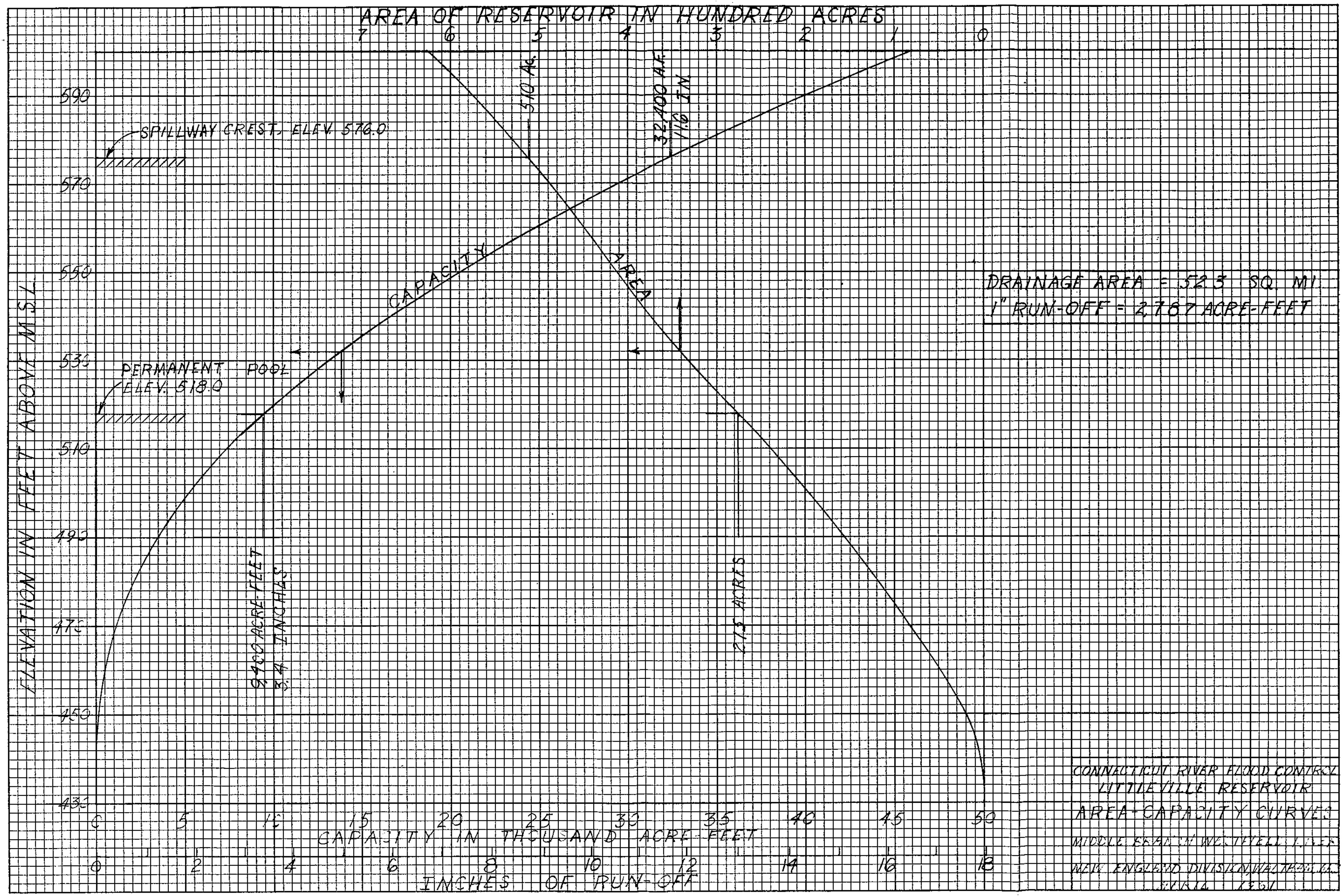
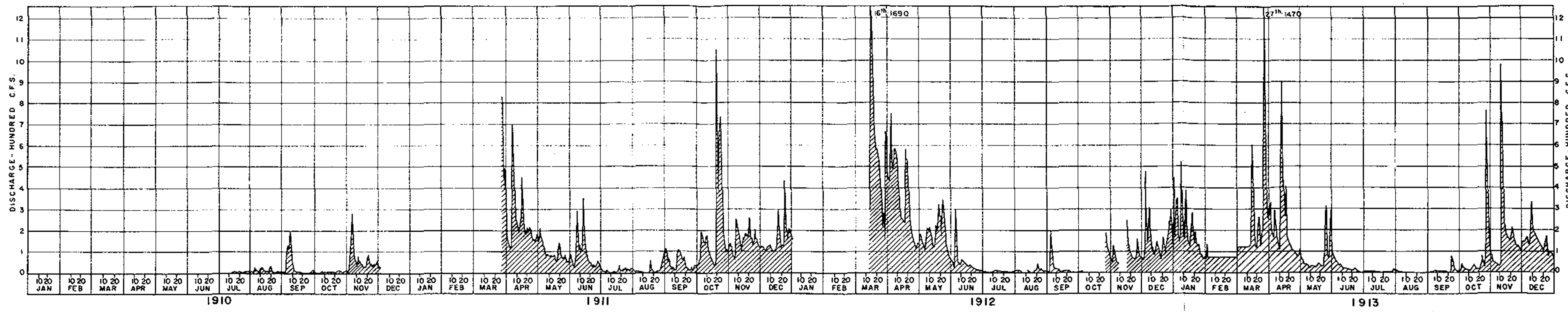
U.S. ARMY
ROTARY
TOP OF DAM EL. 596.0
WATER SUPPLY INTAKE TOWER
SERVICE BRIDGE
9'-0" DIVERSION CONDUIT
48" WATER SUPPLY PIPE
FLOOD CONTROL INLET CHANNEL
MAINTENANCE ROAD
SPILLWAY APPROACH CHANNEL
FLOOD CONTROL SHAFT & OPERATING HOUSE
SPILLWAY WEIR
Crest El. 576.0
Curve Data
Δ = 65°30'00"
R = 500.00'
T = 321.61'
L = 571.60'
TOP OF DIKE
Parking Area
ACCESS BRIDGE EL. 594.0
ACCESS ROAD
UTILITY BLDG
DISCHARGE CHANNEL
Future Waterpipe to Filter Plant
Future valve for downstream low flow regulation
MIDDLE BRANCH
WESTFIELD RIVER
NORTH CHESTER ROAD
EAST RIVER ROAD
GOSS HILL ROAD
To Littleville
To Huntington
Garage
OPERATOR'S QUARTERS
HAMPDEN CO.
HAMPSHIRE CO.
TOWN OF CHESTER
TOWN OF HUNTINGTON
GRAPHIC SCALE
1" = 100'
GENERAL NOTES:
Elevations refer to Mean Sea Level Datum.
Contour interval equals five feet.
Origin of Coordinates is a local grid. County Bound at Hampden and Hampshire is N50,000 - E50,000.
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.
CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE DAM
GENERAL PLAN
MIDDLE BRANCH, WESTFIELD RIVER, MASS.
DATE APRIL 1961
SCALE: 1" = 100'
DRAWING NUMBER
CT-1-4712

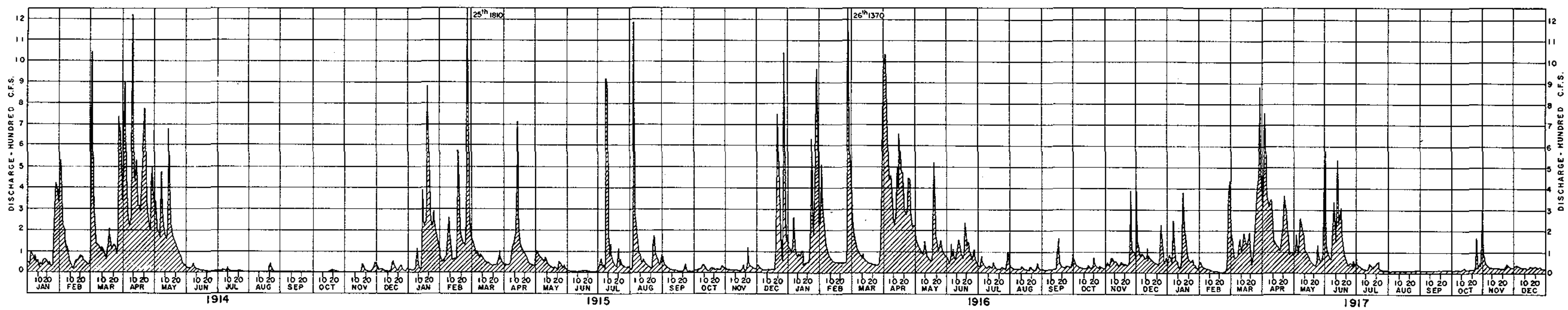
PLATE NO. II-4

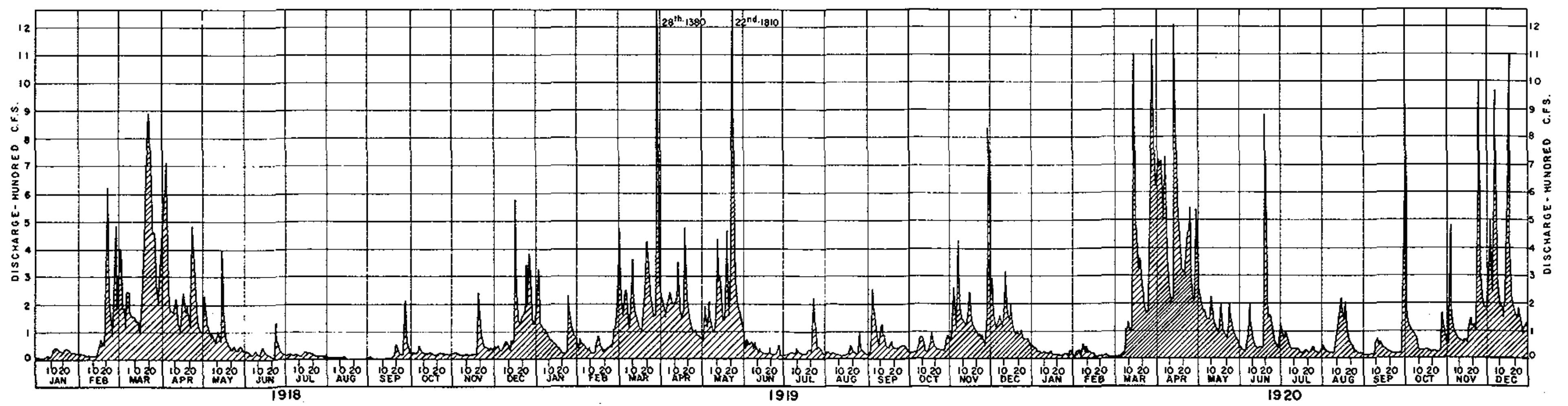


AREA OF RESERVOIR IN HUNDRED ACRES
7
6
5
4
3
2
1
0
590
570
550
530
510
490
470
450
430
ELEVATION IN FEET ABOVE M.S.L.
SPILLWAY CREST, ELEV. 576.0
510 Ac.
32,400 A.F.
11.6 IN.
CAPACITY
AREA
DRAINAGE AREA = 52.3 SQ. MI.
1" RUN-OFF = 2767 ACRE-FEET
PERMANENT POOL
ELEV. 518.0
9400 ACRE-FEET
3.4 INCHES
215 ACRES
0
5
10
15
20
25
30
35
40
45
50
CAPACITY IN THOUSAND ACRE-FEET
0
2
4
6
8
10
12
14
16
18
INCHES OF RUN-OFF
CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE RESERVOIR
AREA-CAPACITY CURVES
MIDDLE BRANCH WESTFIELD RIVER
NEW ENGLAND DIVISION, WALTHAM, MASS.

PLATE NO. I-5







NOTES

1. These hydrographs are the daily average stream flow record of Middle Branch Westfield River, Goss Heights, Massachusetts from the tributary drainage area of 52.6 Square Miles.

2. Instantaneous peak discharges are shown where available.

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DR. BY R.J.B. | TR. BY | CK. BY E.P.S.

SUBMITTED
CHIEF, HYD & HYD SECTION
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, HYD. & HYD. SECTION
APPROVAL RECOMMENDED
CHIEF P. & R. BRANCH

CONNECTICUT RIVER FLOOD CONTROL

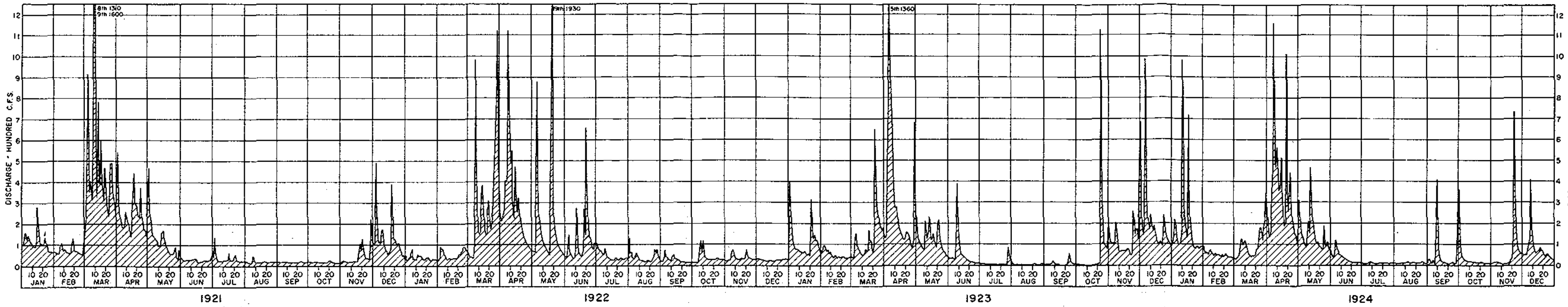
LITTLEVILLE RESERVOIR

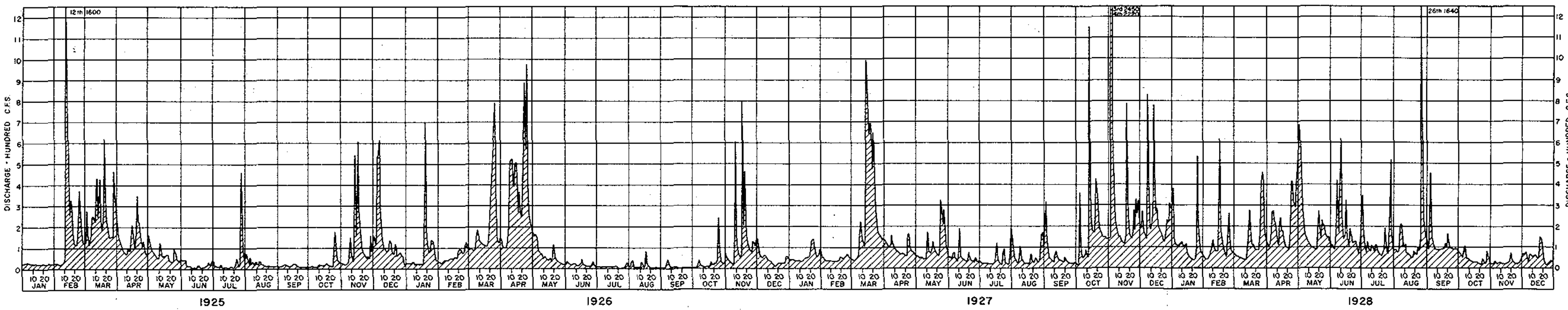
HYDROGRAPHS NO. 1

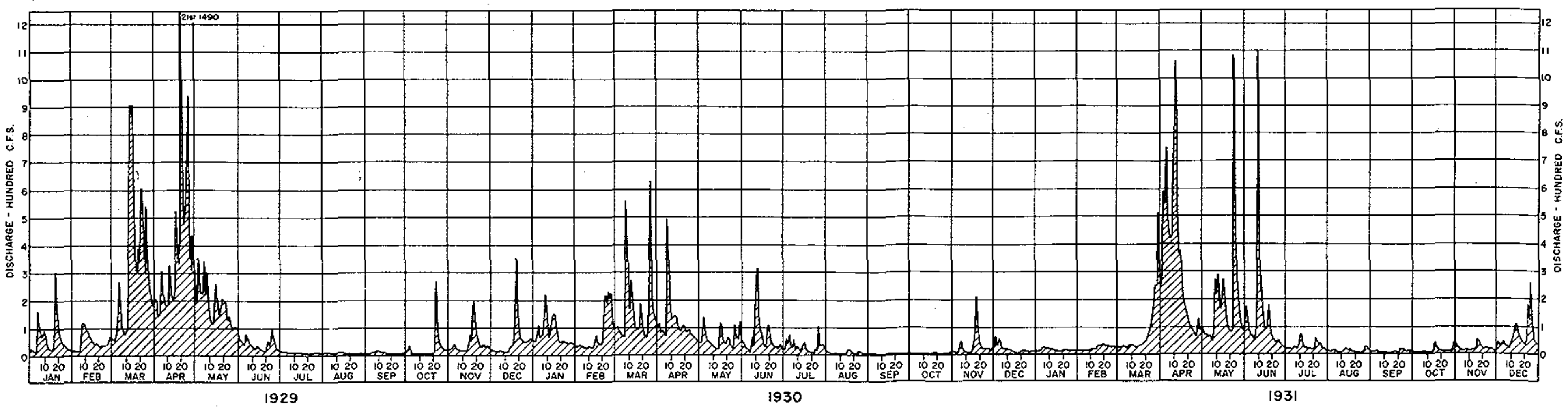
MIDDLE BRANCH WESTFIELD RIVER, MASS.

APPROVED:
CHIEF ENGINEERING DIVISION
DATE APRIL 1961

SCALE
DRAWING NUMBER
SHEET







NOTES

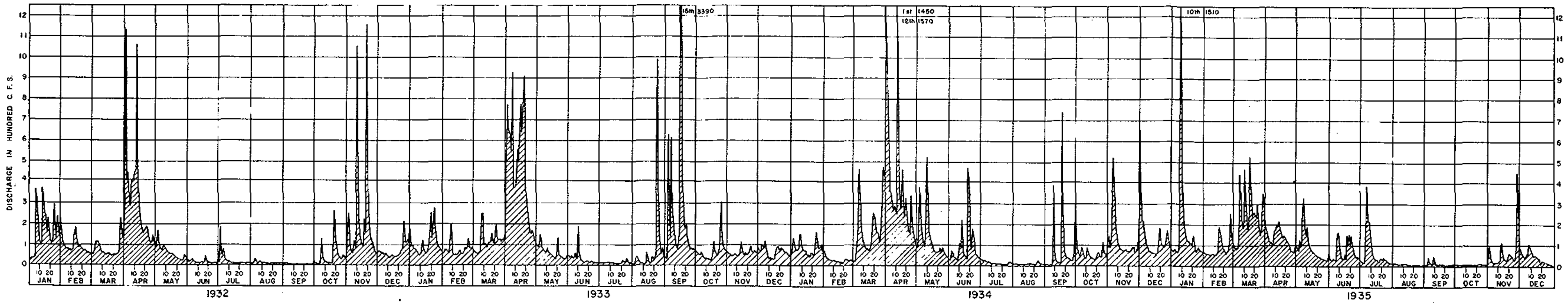
1. These hydrographs are the daily average stream flow record of Middle Branch Westfield River, Goss Heights, Massachusetts from the tributary drainage area of 52.6 Square Miles.

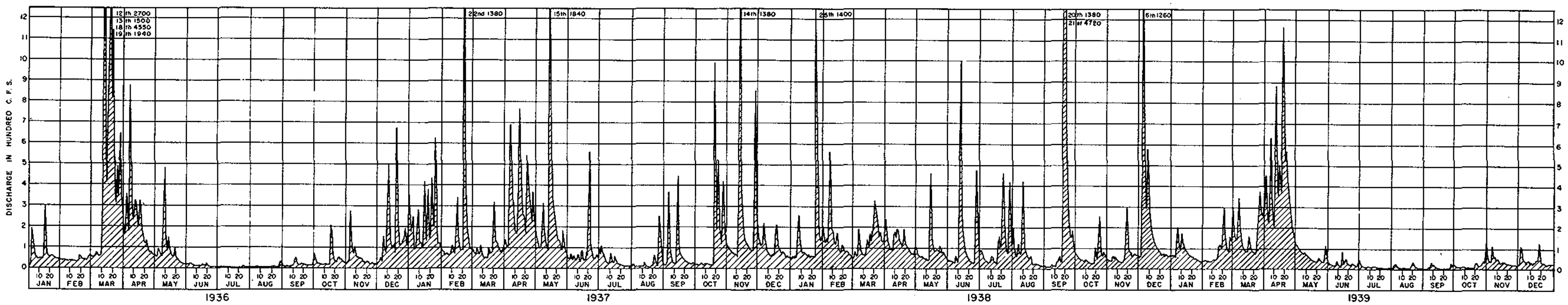
2. Instantaneous peak discharges are shown where available.

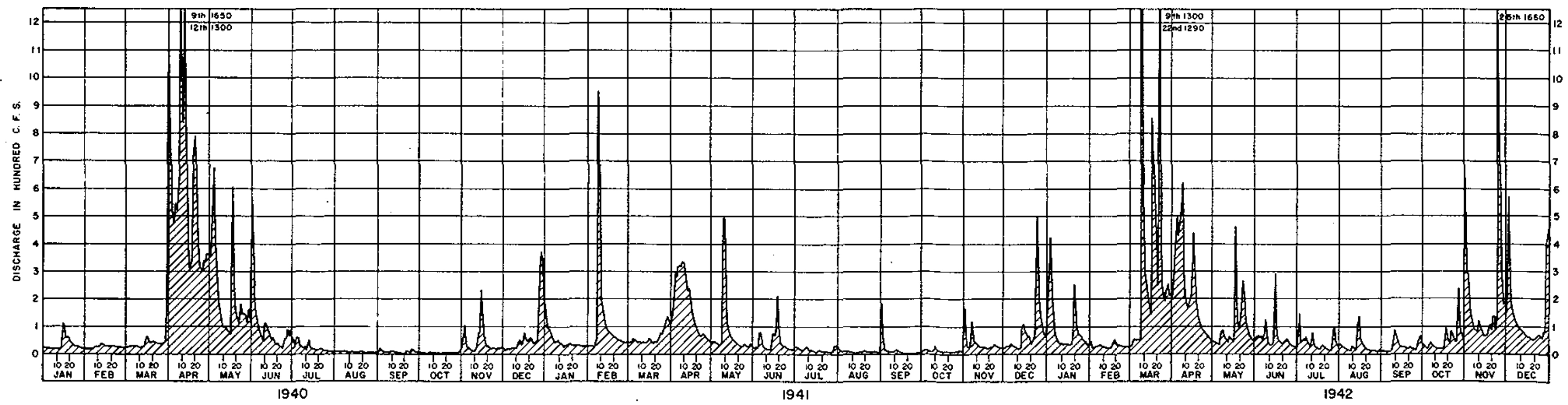
REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DR. BY R.J.B. / TR. BY / CK. BY E.P.S.	CONNECTICUT RIVER FLOOD CONTROL
SUBMITTED — CHIEF HYD. & HYD. SECTION	LITTLEVILLE RESERVOIR
PROJECT ENGINEER	HYDROGRAPHS NO. 2
APPROVAL RECOMMENDED — CHIEF, HYD. & HYD. SECTION	MIDDLE BRANCH WESTFIELD RIVER, MASS.
APPROVAL RECOMMENDED — CHIEF P. & R. BRANCH	APPROVED — CHIEF ENGINEERING DIVISION — DATE APRIL 1961
	SCALE
	DRAWING NUMBER
	SHEET







NOTES

1. These hydrographs are the daily average stream flow record of Middle Branch Westfield River, Goss Heights, Massachusetts from the tributary drainage area of 52.6 Square Miles.

2. Instantaneous peak discharges are shown where available.

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DR. BY R.J.B. | TR. BY | CK. BY E.P.S.

SUBMITTED — CHIEF, HYD. & HYD. SECTION

PROJECT ENGINEER

APPROVAL RECOMMENDED — CHIEF, DESIGN BRANCH

APPROVAL RECOMMENDED — CHIEF P. & R. BRANCH

CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE RESERVOIR

HYDROGRAPHS NO. 3

MIDDLE BRANCH WESTFIELD RIVER, MASS.

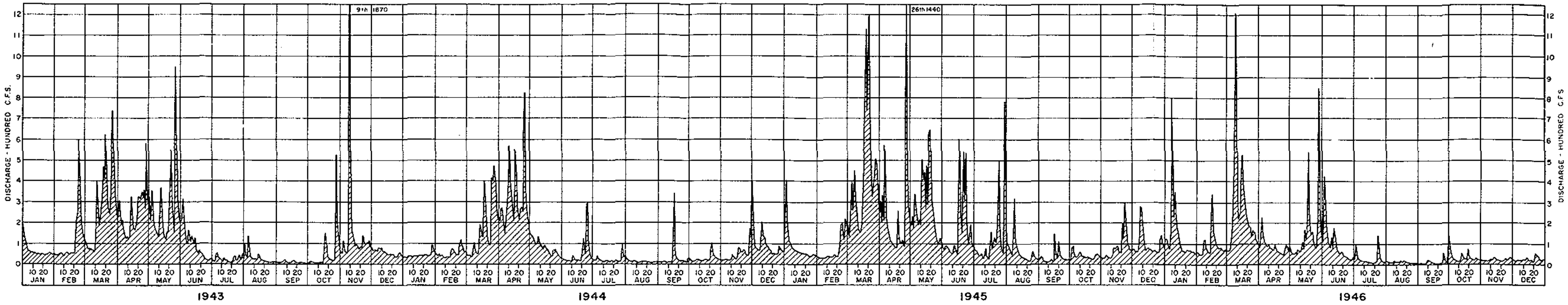
APPROVED — CHIEF ENGINEERING DIVISION | DATE

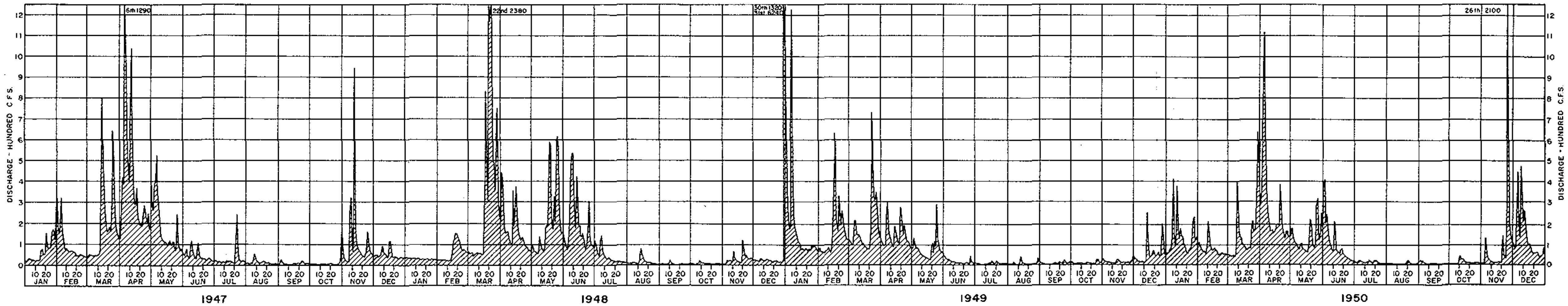
SCALE | SPEC. NO. CIV. ENG.-19-016-

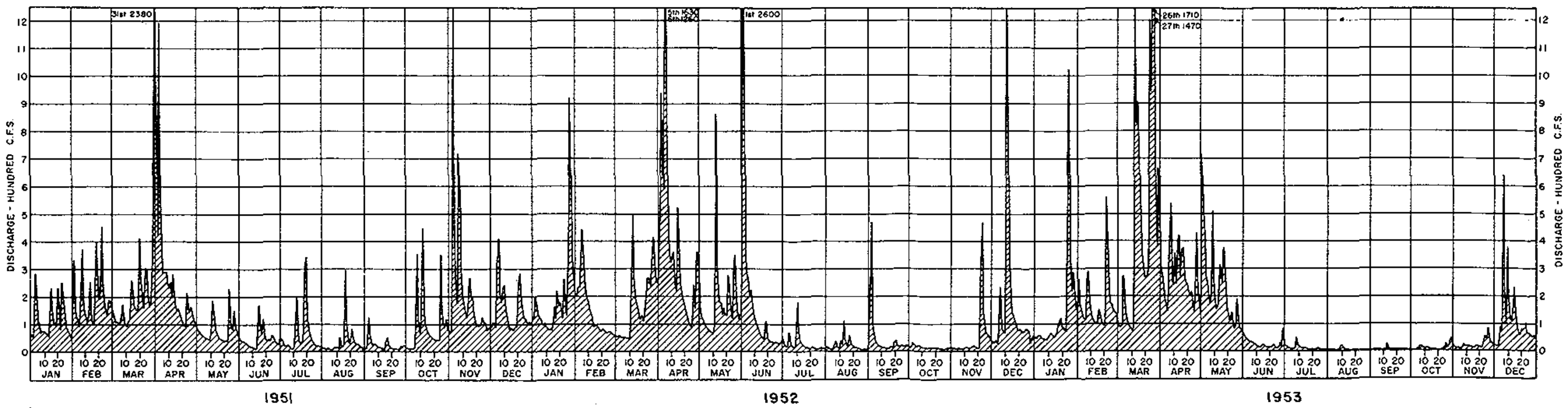
DRAWING NUMBER

SHEET

PLATE NO. I - 8







NOTES

1. *These hydrographs are the daily average stream flow record of Middle Branch Westfield River, Goss Heights, Massachusetts from the tributary drainage area of 52.6 Square Miles.*

2. *Instantaneous peak discharges are shown where available.*

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DR. BY R.J.B. | TR. BY | CK. BY E.P.S.

SUBMITTED

PROJECT ENGINEER

APPROVAL RECOMMENDED

CHIEF, HYD. & HYD. SECTION

APPROVAL RECOMMENDED

CHIEF P. & R. BRANCH

CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE RESERVOIR

HYDROGRAPHS NO. 4

MIDDLE BRANCH WESTFIELD RIVER, MASS.

APPROVED

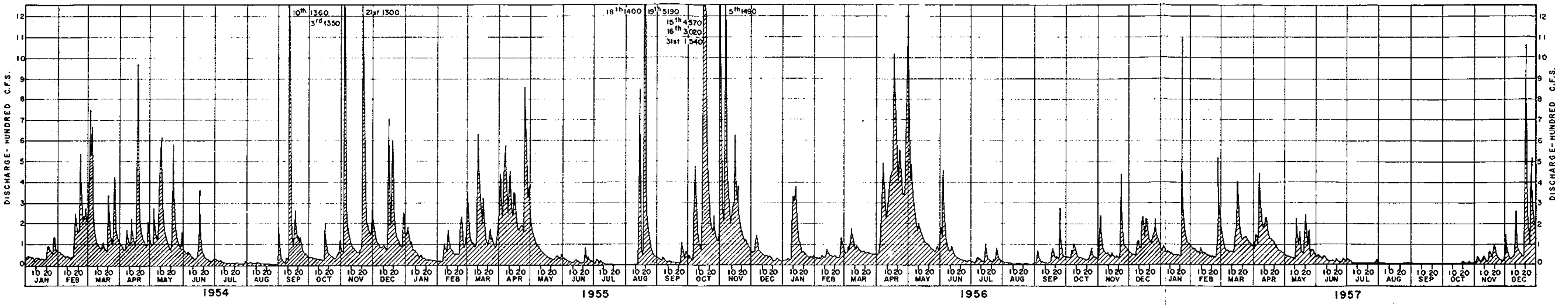
CHIEF ENGINEERING DIVISION

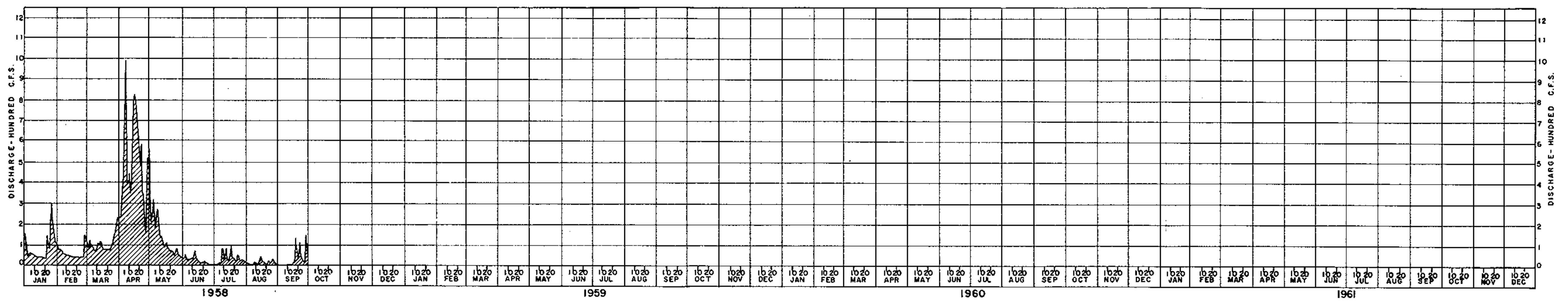
DATE APRIL 1961

SCALE

DRAWING NUMBER

SHEET

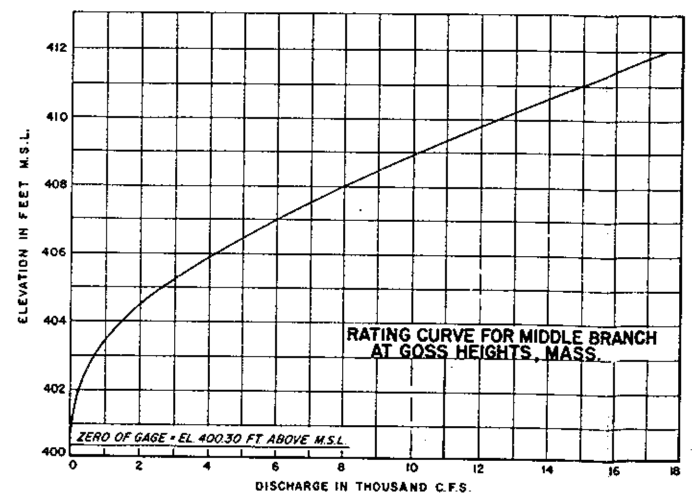




NOTES

1. These hydrographs are the daily average stream flow record of Middle Branch Westfield River, Goss Heights, Massachusetts from the tributary drainage area of 52.6 Square Miles.

2. Instantaneous peak discharges are shown where available.



REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DR. BY R.J.B. | TR. BY | CK. BY E.P.S.

SUBMITTED

PROJECT ENGINEER

APPROVAL RECOMMENDED — CHIEF HYD. & HYD. SECTION

APPROVAL RECOMMENDED — CHIEF P. & R. BRANCH

APPROVED — CHIEF ENGINEERING DIVISION

DATE APRIL 1961

CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE RESERVOIR

HYDROGRAPHS NO. 5

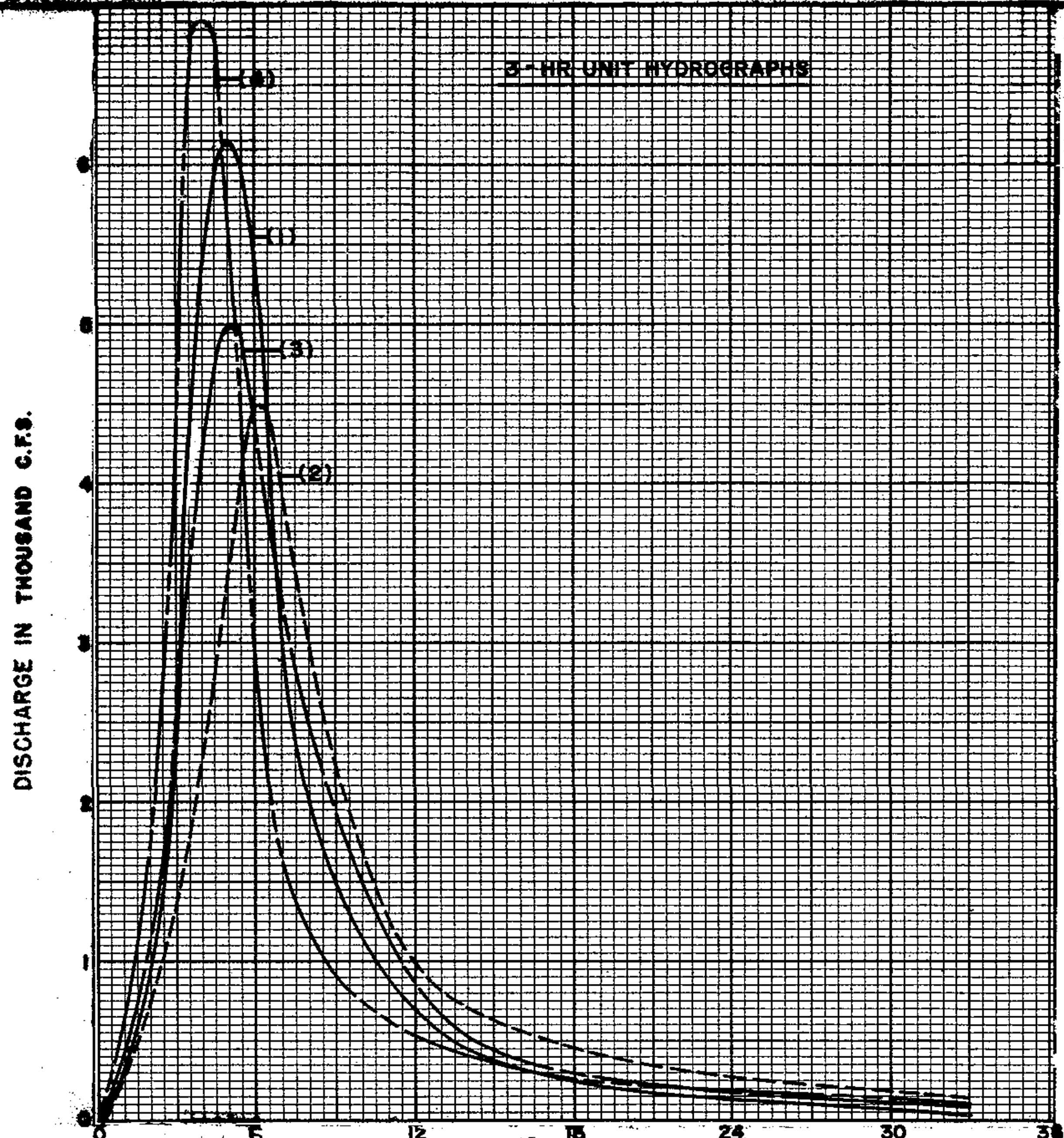
MIDDLE BRANCH WESTFIELD RIVER, MASS.

SCALE

DRAWING NUMBER

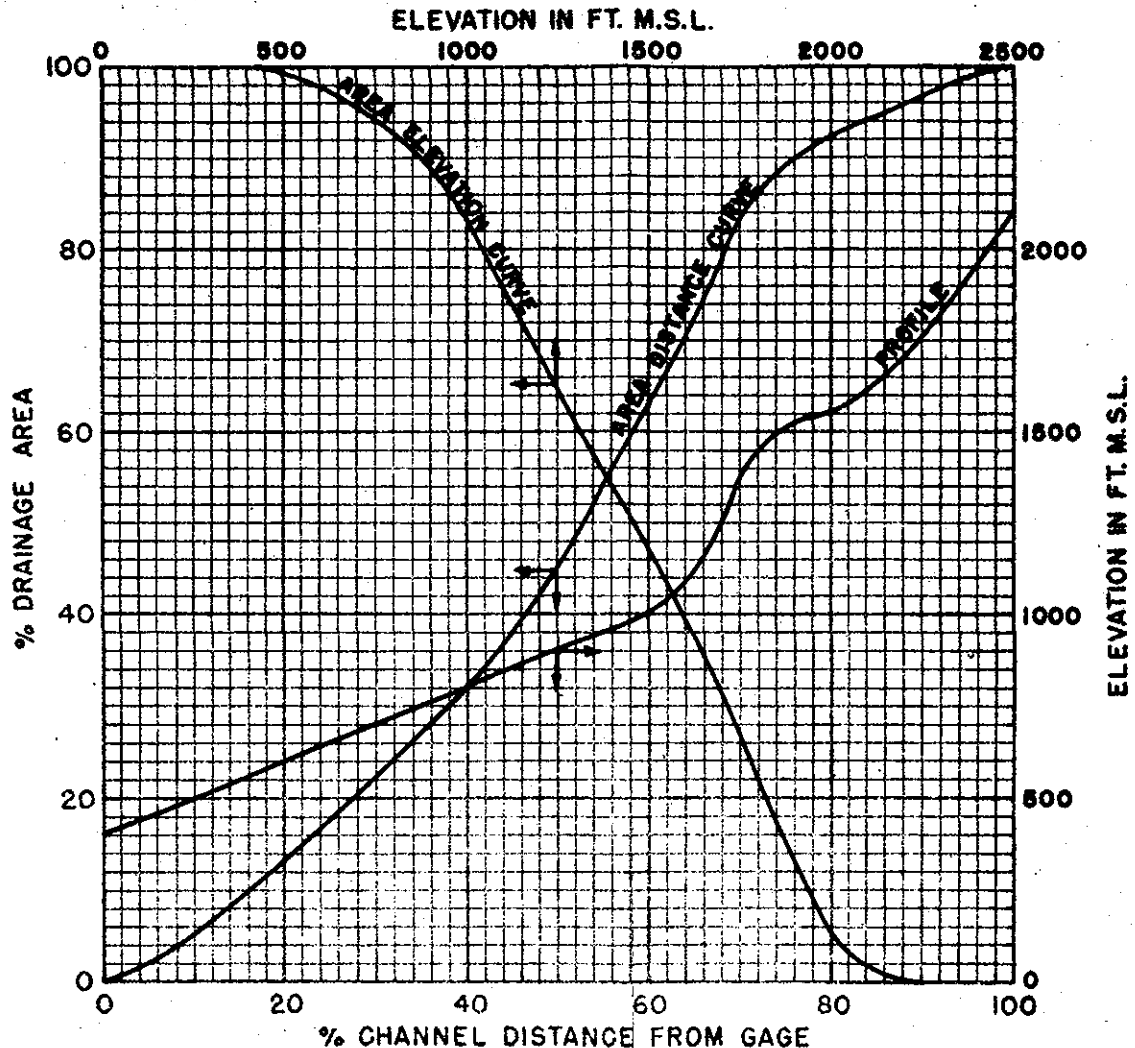
SHEET

DEPARTMENT OF THE ARMY | CORPS OF ENGINEERS



DRAINAGE AREA CHARACTERISTICS

DRAINAGE AREA	52.6 sq.mi.		L	19.3 mi.
MAXIMUM ELEVATION	2234 ft.m.s.l.		L_{ca}	10.4 mi.
MINIMUM ELEVATION	390 ft.m.s.l.		$(LL_{ca})^{0.3}$	4.91
MEAN ELEVATION (weighted)	1350 ft.m.s.l.		DRAINAGE DENSITY	mi/sq.mi.
LAND SLOPE	ft./mi.		MAP SCALE	1:62,500
MAIN STREAM SLOPE	74 ft./mi.		METHOD OF FLOW SEPARATION	
			BASIN SHAPE FACTOR	7.08



DATA FROM OBSERVED UNIT HYDROGRAPHS

DATE OF RAINFALL	LEGEND	AVE. P (In.)	RAINFALL EXCESS DURATION (hr.)	RAINFALL EXCESS AMOUNT (In.)	L_{cP} (mi.)	STAGE RECORD	Q_{pR} (cfs.)	Q_p tr= hrs. (cfs.)	t_{pR} (hr.)	t_p (hr.)	t_v (hr.)	C_{tR}	C_p640	K_m (hr.)	T_c (hr.)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
18-19 AUGUST 1955	(1) ———	7.10	5	2.46	DNSTR	REC	5900	6150	2.3	3.5	4.3	0.47	258	3.7	1.5
14-15 OCTOBER 1955	(2) - - -	7.70	9	2.08	DNSTR	REC	2910	4500	4.1	4.5	5.0	0.84	227	9.8	4.2
25-26 NOVEMBER 1950	(3) —— -	3.60	2	1.31	UNIF	REC	5550	5000	2.8	3.5	5.0	0.57	2.95	3.2	4.0
21 SEPTEMBER 1938	(4) —— - -	4.50	2-1/2	2.48	UNIF	REC	7500	6900	1.9	2.6	2.9	0.39	270	1.5	1.5

CONNECTICUT RIVER FLOOD CONTROL

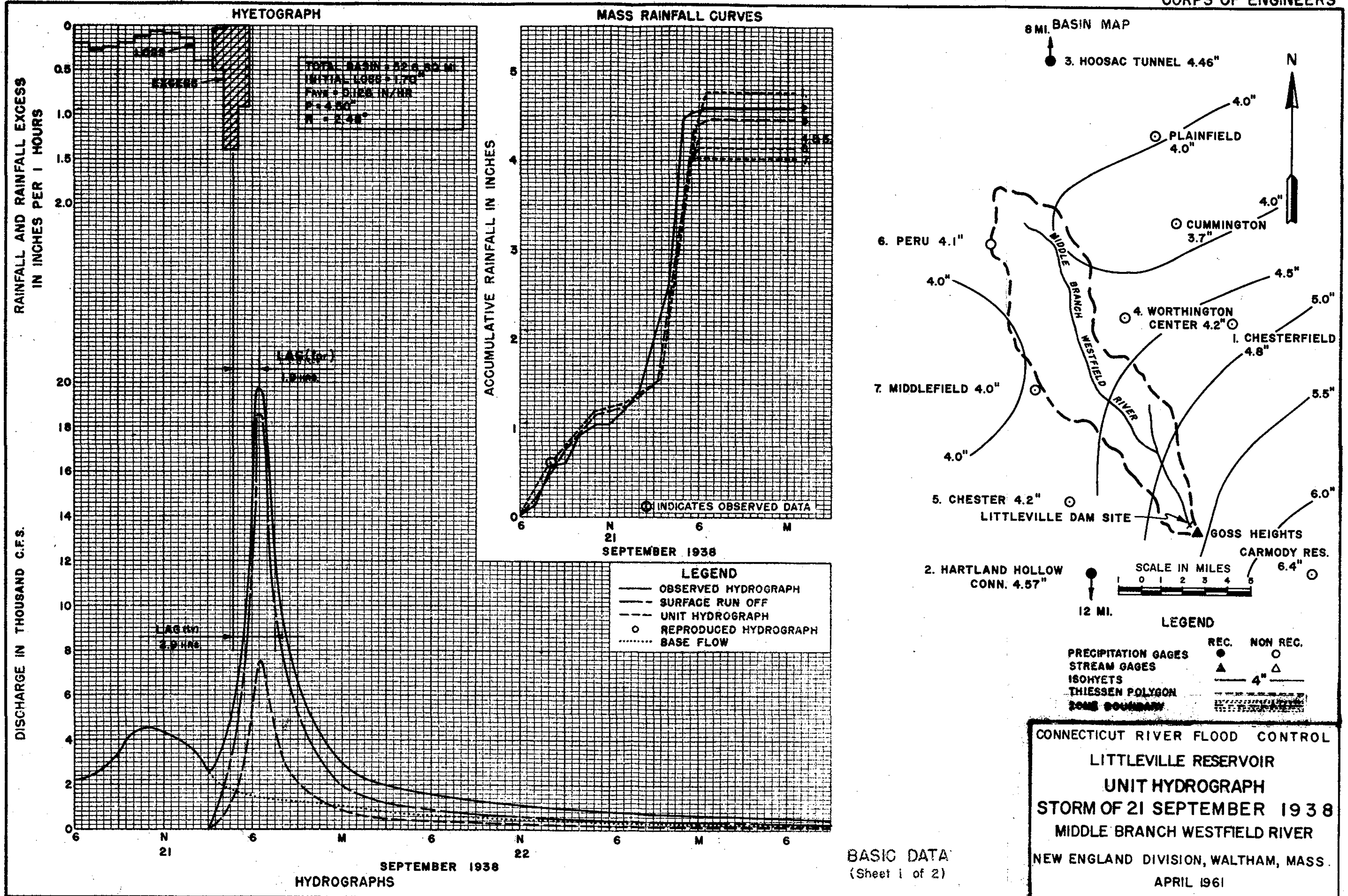
LITTLEVILLE RESERVOIR

UNIT HYDROGRAPHS
PERTINENT DATA

MIDDLE BRANCH WESTFIELD RIVER

NEW ENGLAND DIVISION, WALTHAM, MASS.

APRIL 1961



CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE RESERVOIR

UNIT HYDROGRAPH

STORM OF 21 SEPTEMBER 1938

MIDDLE BRANCH WESTFIELD RIVER

NEW ENGLAND DIVISION, WALTHAM, MASS.

APRIL 1961

DEPARTMENT OF THE ARMY

CORPS OF ENGINEERS

UNIT HYDROGRAPH BASIC DATA SHEET

(7) STREAM AND STATION Middle Branch, Westfield River at Goss Heights, Massachusetts LAT. 42°15'31" LONG. 72°52'23"

(8) DATE OF STORM 21 September 1938 (9) OFFICE New England Division

(10) DRAINAGE AREA 52.6 SQ.MI. (11) L 19.3 MI. (12) L_{ca} 10.4 MI. (13) $(LL_{ca})^{0.3}$ 4.91

(14) AVERAGE RAINFALL 4.50 IN. (15) t_R $2\frac{1}{2}$ HRS. (16) DIRECT RUNOFF 2.48 IN.

(17) Q_{pR} 7500 CFS. (18) q_{pR} 143 CFS/SQ.MI. (19) Q_p 6900 CFS. (20) t_{pR} 1.9 HRS.

(21) t_p 2.6 HRS. (22) t_v 2.9 HRS. (23) C_{tR} 0.39 (24) C_p640 270 W_{50} 2.2 HRS. W_{75} 1.2 HRS.

TIME September 1938 (25)	OBSERVED DISCHARGE (1000 CFS) (26)	ESTIMATED BASE FLOW (1000 CFS) (27)	DIRECT RUNOFF (1000 CFS) (28)	$2\frac{1}{2}$ OBSERVED HR UNIT HYDROGRAPH (1000 CFS) (29)	ADJUSTED 3 HR UNIT HYDROGRAPH (1000 CFS) (30)	REPRODUCED STORM HYDROGRAPH (1000 CFS) (31)	(32)	(33)
21-2P	3630	3630	0	0	0			
4	3520	1900	1620	650	550			
6	14100	1500	12600	5080	4500			
8	9190	1280	7910	3190	5800			
10	4880	1100	3780	1520	1500			
M	2940	960	1980	800	900			
22-2A	2180	830	1350	540	600			
4	1770	720	1050	420	450			
6	1480	590	890	360	360			
8	1310	510	800	320	280			
10	1150	450	700	280	230			
N	1040	430	610	250	210			
2A	940	370	570	230	190			
4	854	350	500	200	170			
6	782	320	460	190	150			
8	722	300	420	170	130			
10	674	280	390	160	110			
M	626	260	370	150	100			
23-2A	592	250	340	135	90			
4	565	250	320	130	85			
6	538	240	300	120	80			
8	510	230	280	115	75			
10	488	230	260	105	70			
N	466	230	240	95	60			
2P	450	230	220	90	55			
4	430	230	200	80	50			
6	410	230	180	75	45			
8	390	230	160	65	40			
10	375	225	140	55	35			
M	355	235	120	50	30			
24-2A	350	250	100	40	25			
4	337	260	80	30	20			
6	328	270	60	25	15			
8	319	280	40	15	10			
10	310	290	20	10	5			
N	301	290	10	5	0			
Totals	59,302	20,230	39,070	15,570	17,020			

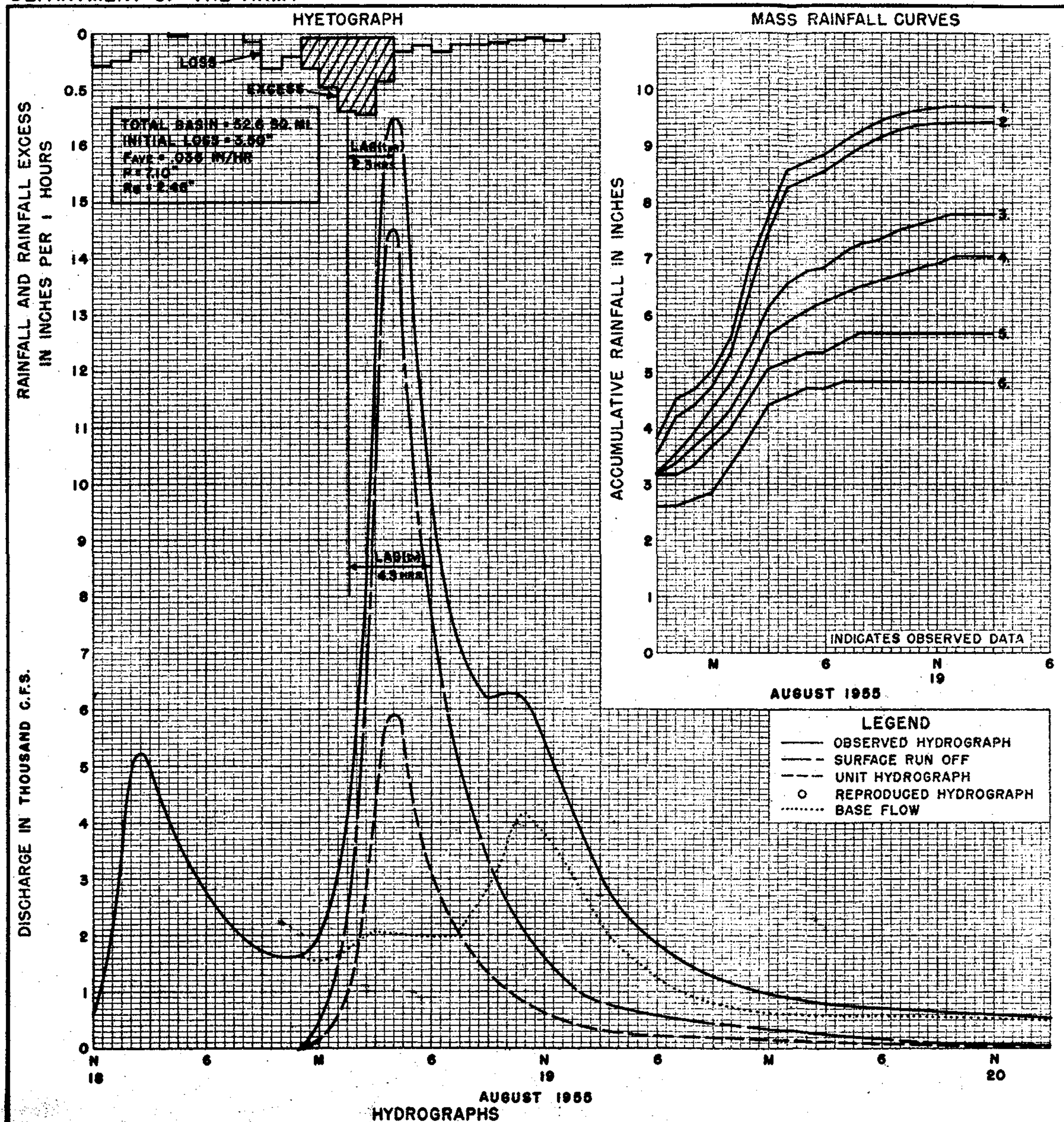
DATE

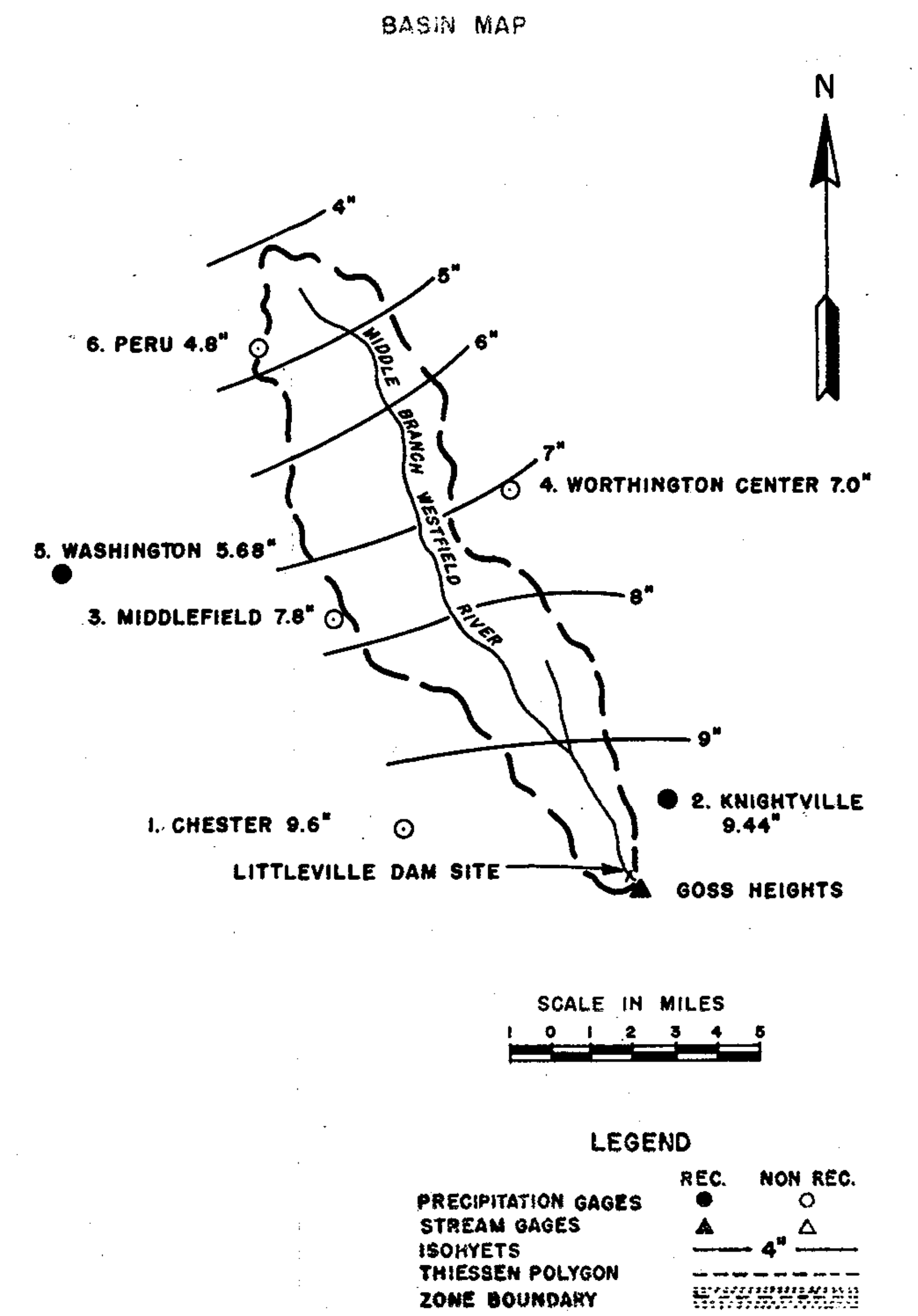
COMPUTED BY

ENG FORM 1 NOV 49 1823

 50 6617

DEPARTMENT OF THE ARMY CORPS OF ENGINEERS





BASIC DATA
(Sheet 1 of 2)

CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE RESERVOIR

UNIT HYDROGRAPH

STORM OF 18-19 AUGUST 1955

MIDDLE BRANCH WESTFIELD RIVER

NEW ENGLAND DIVISION, WALTHAM, MASS.
APRIL 1961

ENG FORM 1 OCT 50 1822 SUPERSEDES ENG. FORM 1822 1 NOV. 49, WHICH MAY BE USED UNTIL STOCK IS EXHAUSTED

PLATE NO. I-14

DEPARTMENT OF THE ARMY

UNIT HYDROGRAPH BASIC DATA SHEET

CORPS OF ENGINEERS

(7) STREAM AND STATION Middle Branch, Westfield River at Goss Heights, Massachusetts LAT. 42° 15' 31" LONG. 72° 52' 23"

(8) DATE OF STORM 18-19 August 1955 (9) OFFICE New England Division

(10) DRAINAGE AREA 52.6 SQ.MI. (11) L 19.3 MI. (12) L_{ca} 10.4 MI. (13) $(LL_{ca})^{0.3}$ 4.91

(14) AVERAGE RAINFALL 7.10 IN. (15) t_R 5 HRS. (16) DIRECT RUNOFF 2.46 IN.

(17) Q_{pR} 5900 CFS. (18) q_{pR} 112 CFS/SQ.MI. (19) Q_p 6150 CFS. (20) t_{pR} 2.3 HRS.

(21) t_p 3.5 HRS. (22) t_v 4.3 HRS. (23) C_{tR} 0.47 (24) C_p640 258 W_{50} 3.5 HRS. W_{75} 2.0 HRS.

TIME August 1955 (25)	OBSERVED DISCHARGE (1000 CFS) (26)	ESTIMATED BASE FLOW (1000 CFS) (27)	DIRECT RUNOFF (1000 CFS) (28)	OBSERVED 5 HR UNIT HYDROGRAPH (1000 CFS) (29)	ADJUSTED 3 HR UNIT HYDROGRAPH (1000 CFS) (30)	REPRODUCED STORM HYDROGRAPH (1000 CFS) (31)	(32)	(33)
18-10P	1630	1630	0	0	0			
M	1920	1520	400	165	270			
19-2A	5600	1880	3720	1510	2520			
4	16500	2000	14500	5900	6150			
6	9840	1840	8000	3250	3120			
8	6660	2280	4380	1780	1450			
10	6260	3560	2500	1015	870			
N	5430	3770	1660	675	530			
2P	3800	2760	1040	425	390			
4	2510	1710	800	325	280			
6	1840	1170	670	270	210			
8	1410	820	590	240	150			
10	1150	640	510	205	110			
M	980	550	430	175	95			
20-2A	860	500	360	145	85			
4	780	480	300	120	75			
6	720	480	240	100	65			
8	650	460	190	75	55			
10	600	430	170	70	55			
N	560	410	150	60	45			
2P	510	370	140	55	35			
4	460	330	130	55	35			
6	410	290	120	50	30			
8	370	260	110	45	25			
10	350	250	100	40	20			
M	330	240	90	35	15			
21-2A	310	225	85	35	15			
4	290	210	80	35	15			
6	270	195	75	30	15			
8	250	180	70	30	15			
10	230	165	65	25	10			
N	210	150	60	25	10			
2P	195	140	55	20	10			
4	185	140	45	20	10			
6	175	140	35	15	5			
8	165	140	25	10	5			
10	155	140	15	5	0			
M	145	145	0	0	0			
Totals	74,710	32,600	41,910	17,035	16,795			

DATE

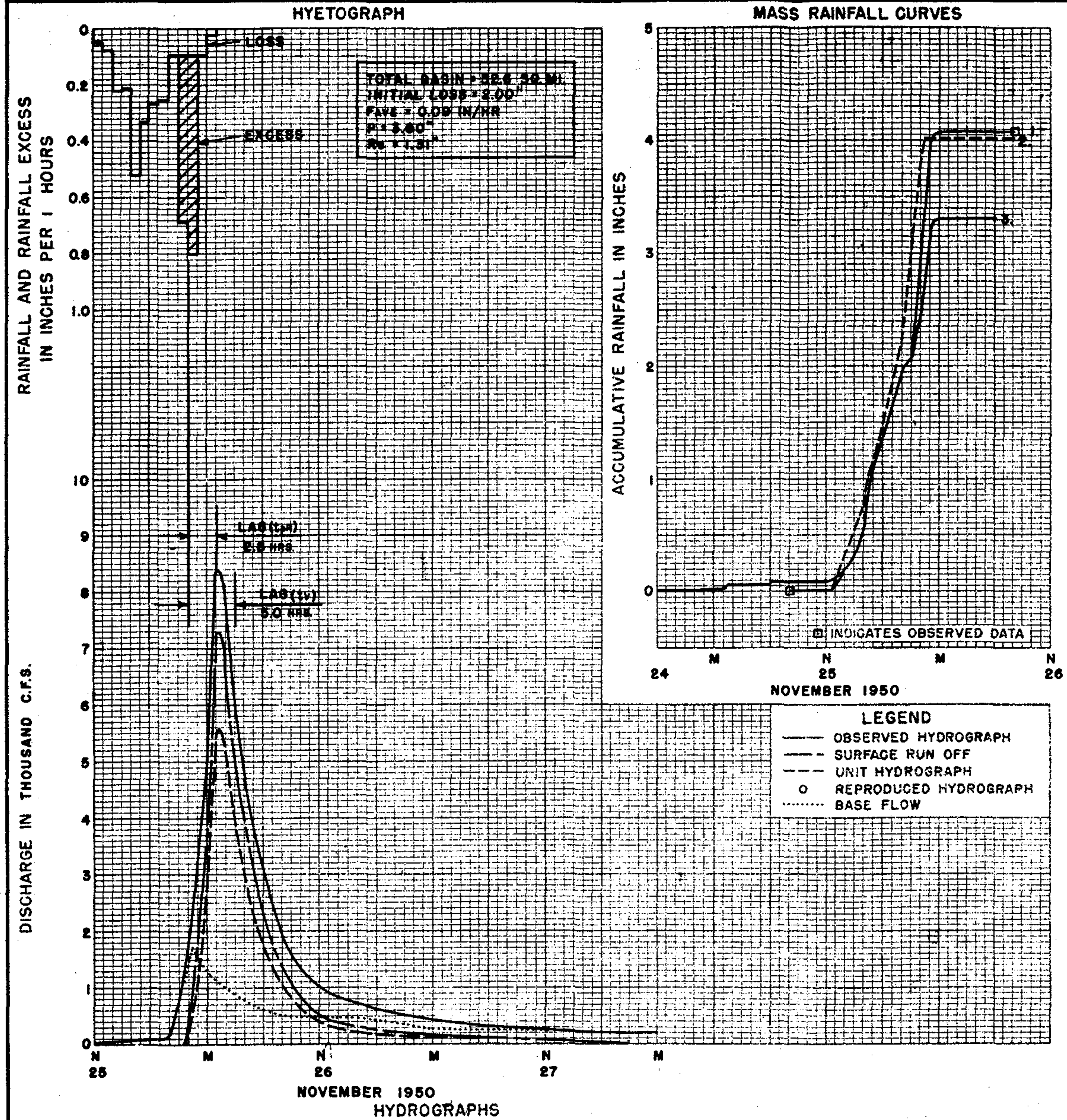
COMPUTED BY

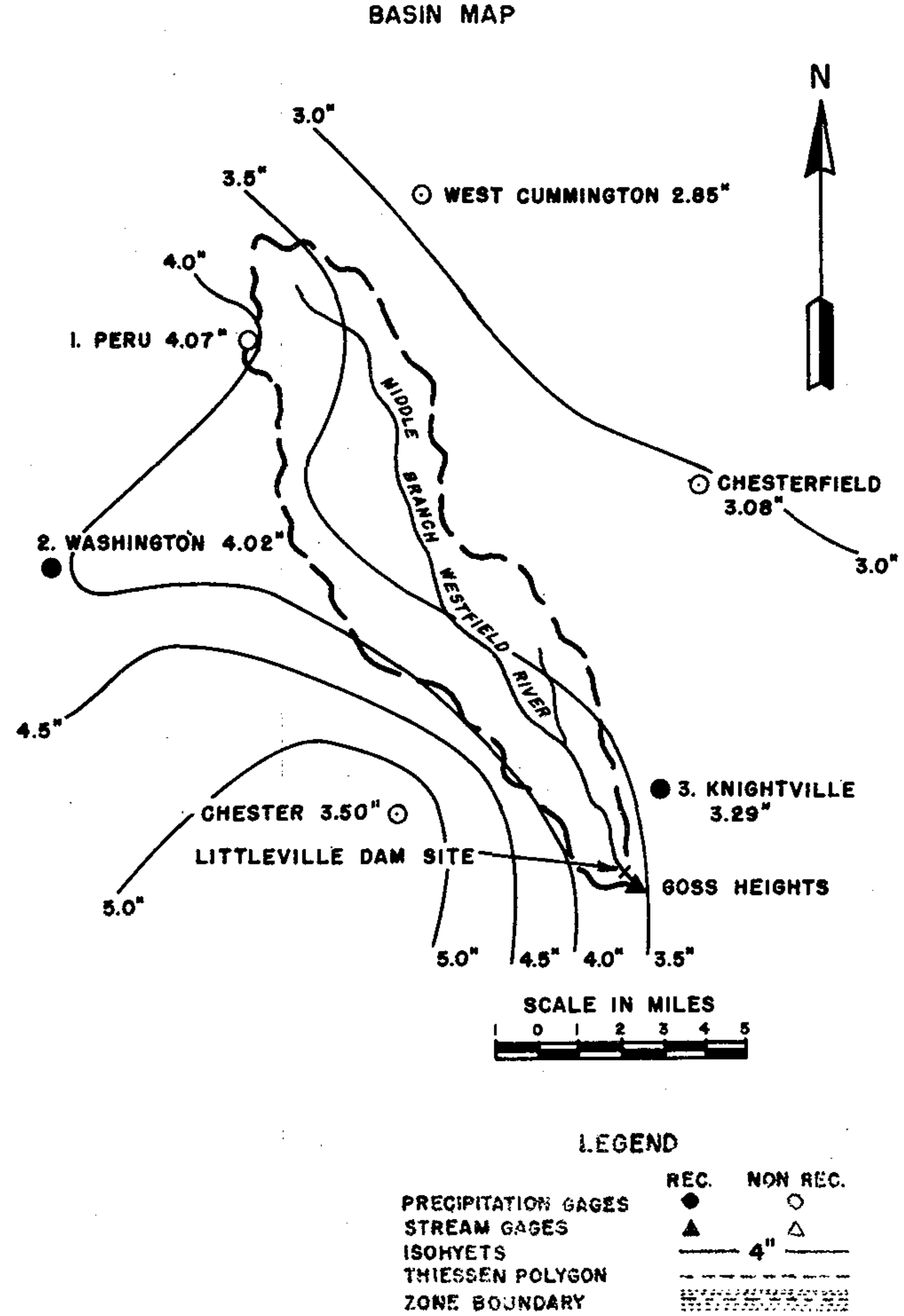
ENG FORM 1823
1 NOV 49

C51636

DEPARTMENT OF THE ARMY

CORPS OF ENGINEERS





BASIC DATA
(Sheet 1 of 2)

CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE RESERVOIR

UNIT HYDROGRAPH
STORM OF 25-26 NOVEMBER 1950

MIDDLE BRANCH WESTFIELD RIVER

NEW ENGLAND DIVISION, WALTHAM, MASS.
APRIL 1961

ENG FORM 1 OCT. 50 1822 SUPERSEDES ENG. FORM 1822 1 NOV. 49, WHICH MAY BE USED UNTIL STOCK IS EXHAUSTED

PLATE NO. I-16

DEPARTMENT OF THE ARMY — CORPS OF ENGINEERS

UNIT HYDROGRAPH BASIC DATA SHEET

(SHEET 2 OF 2)

(7) STREAM AND STATION Middle Branch, Westfield River at Goss Heights, Massachusetts LAT. 42°15'31" LONG. 72°52'23"

(8) DATE OF STORM 25-26 November 1950 (9) OFFICE New England Division

(10) DRAINAGE AREA 52.6 SQ.MI. (11) L 19.3 MI. (12) L_{ca} 10.4 MI. (13) $(LL_{ca})^{0.3}$ 4.91

(14) AVERAGE RAINFALL 3.60 IN. (15) t_R 2 HRS. (16) DIRECT RUNOFF 1.31 IN.

(17) Q_{pR} 5550 CFS. (18) q_{pR} 105.5 CFS/SQ.MI. (19) Q_p 5,000 CFS. (20) t_{pR} 2.8 HRS.

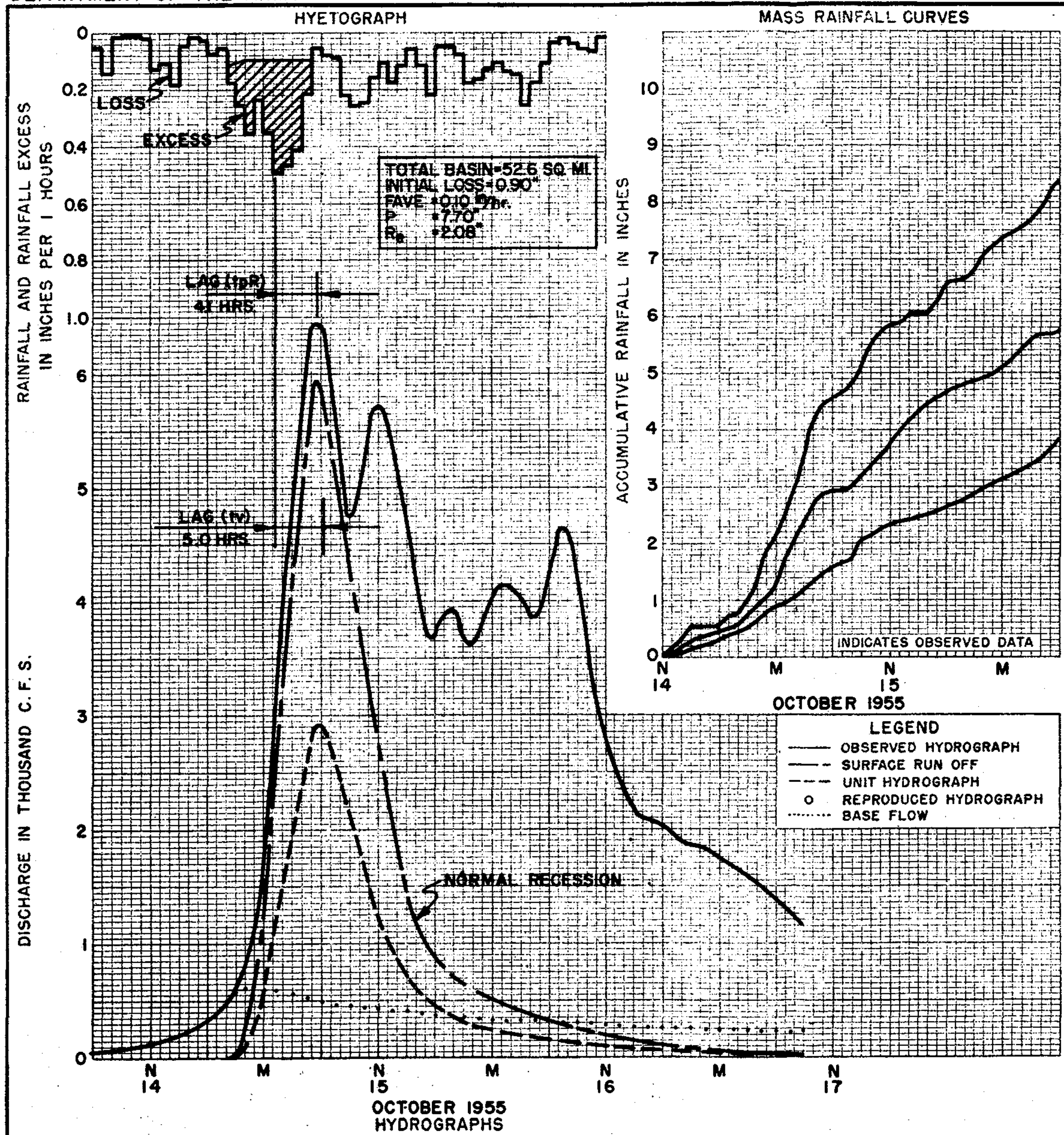
(21) t_p 3.5 HRS. (22) t_v 5.0 HRS. (23) C_{tR} 0.57 (24) $C_p{}^{640}$ 295 W_{50} 4.3 HRS. W_{75} 2.4 HRS.

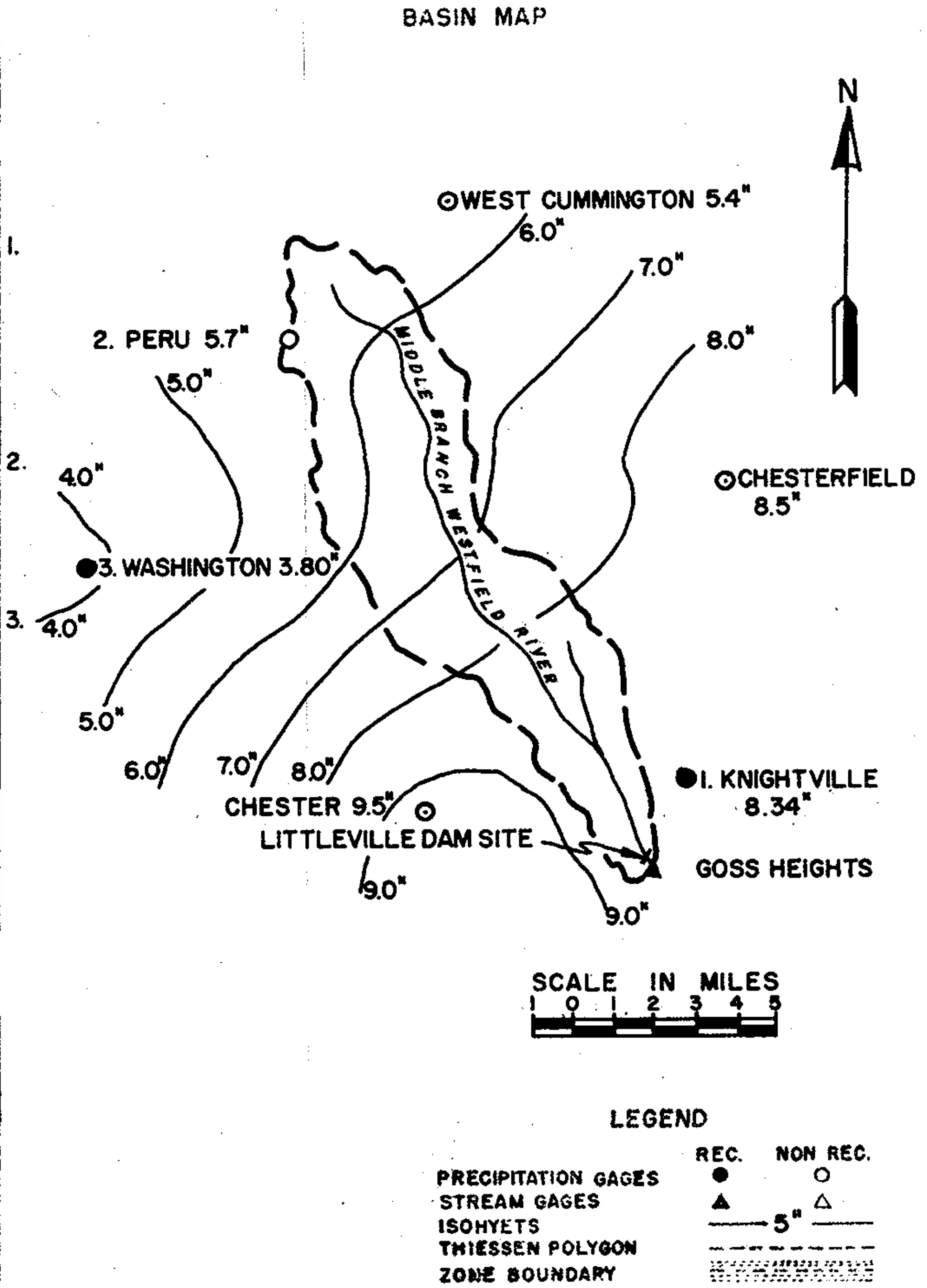
TIME November 1950 (25)	OBSERVED DISCHARGE (1000 CFS) (26)	ESTIMATED BASE FLOW (1000 CFS) (27)	DIRECT RUNOFF (1000 CFS) (28)	OBSERVED 2 HR UNIT HYDROGRAPH (1000 CFS) (29)	ADJUSTED 3 HR UNIT HYDROGRAPH (1000 CFS) (30)	REPRODUCED STORM HYDROGRAPH (1000 CFS) (31)	(32)	(33)
25-10P	2590	1770	820	625	380			
11	2550	1550	2000	1520	1070			
M	5390	1220	4170	3170	2600			
26-1A	8320	1040	7280	5540	4210			
2	7360	970	6390	4860	4970			
3	5930	840	5090	3880	4470			
4	4520	740	3780	2880	3280			
5	3510	680	2830	2160	2500			
6	2830	640	2190	1670	1970			
7	2240	560	1680	1280	1500			
8	1820	520	1300	990	1130			
9	1500	500	1000	760	830			
10	1290	495	795	610	620			
11	1120	490	630	505	495			
N	985	485	500	380	415			
1P	880	480	400	300	360			
2	800	470	330	250	310			
3	750	455	295	225	275			
4	700	430	270	205	250			
5	655	410	245	185	220			
6	605	390	215	165	205			
7	570	370	200	150	185			
8	535	345	190	145	165			
9	500	320	180	135	150			
10	475	310	165	125	140			
11	440	290	150	115	125			
M	410	270	140	105	115			
27-1A	390	260	130	100	100			
2	370	250	120	90	90			
3	350	240	110	85	80			
4	330	230	100	75	75			
5	315	225	90	70	70			
6	305	225	80	60	60			
7	295	225	70	55	50			
8	285	225	60	45	40			
9	275	225	50	40	35			
10	265	225	40	30	30			
11	255	225	30	25	25			
Totals for Entire Hydrograph								
cfs/hr	64,190	20,045	44,145	33,635	33,640			

DATE | COMPUTED BY

ENG FORM 1 NOV 49 1823

PLATE NO. I-17





BASIC DATA
(Sheet 1 of 2)

CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE RESERVOIR
UNIT HYDROGRAPH
STORM OF 14-15 OCTOBER 1955
MIDDLE BRANCH WESTFIELD RIVER

NEW ENGLAND DIVISION, WALTHAM, MASS.
APRIL 1961

DEPARTMENT OF THE ARMY | CORPS OF ENGINEERS

UNIT HYDROGRAPH BASIC DATA SHEET

(SHEET 2 OF 2)

(7) STREAM AND STATION Middle Branch, Westfield River at Goss Heights, Massachusetts LAT. 42°15'31" LONG. 72°52'23"

(8) DATE OF STORM 14-15 October 1955 (9) OFFICE New England Division

(10) DRAINAGE AREA 52.6 SQ.MI. (11) L 19.3 MI. (12) L_{ca} 10.4 MI. (13) $(LL_{ca})^{0.3}$ 4.91

(14) AVERAGE RAINFALL 7.70 IN. (15) t_R 9 HRS. (16) DIRECT RUNOFF 2.08 IN.

(17) Q_{pR} 2910 CFS. (18) q_{pR} 55.4 CFS/SQ.MI. (19) Q_p 4500 CFS. (20) t_{pR} 4.1 HRS.

(21) t_p 4.5 HRS. (22) t_v 5.0 HRS. (23) C_{tR} 0.84 (24) C_p640 227 W_{50} 9.1 HRS. W_{75} 5.2 HRS.

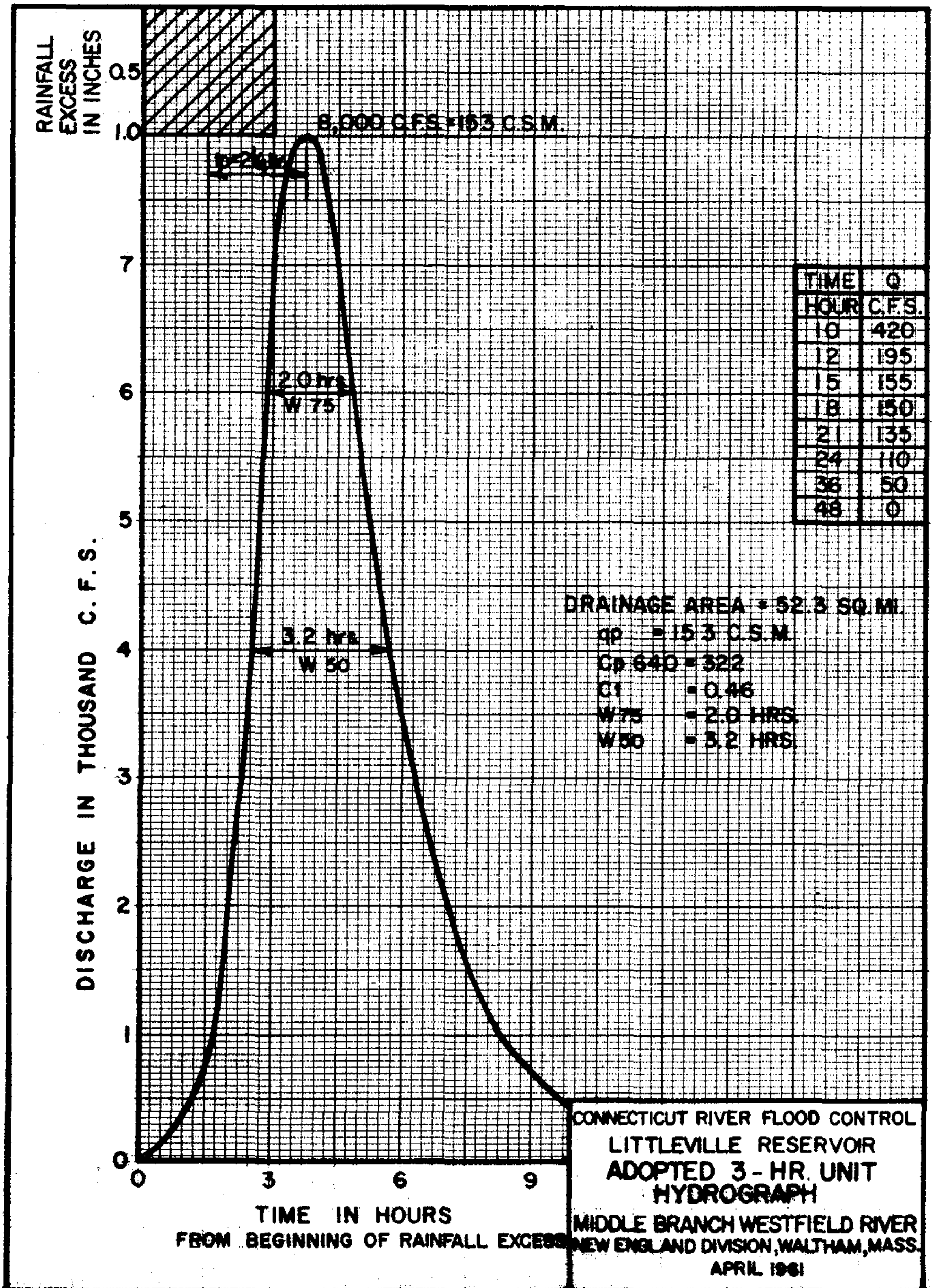
TIME (25)	OBSERVED DISCHARGE (1000 CFS) (26)	ESTIMATED BASE FLOW (1000 CFS) (27)	DIRECT RUNOFF (1000 CFS) (28)	OBSERVED 9 HR UNIT HYDROGRAPH (1000 CFS) (29)	ADJUSTED 3 HR UNIT HYDROGRAPH (1000 CFS) (30)	REPRODUCED STORM HYDROGRAPH (1000 CFS) (31)	(32)	(33)
14-6A	65	65	0	0	0			
9	75	75	0	0	0			
N	90	90	0	0	0			
3P	160	160	0	0	0			
6	340	340	0	0	0			
9	570	560	10	5	15			
M	1750	600	1150	560	1770			
15-3A	4620	550	4070	1990	4350			
6	6440	490	5950	2900	1950			
9	4750	450	4300	2100	850			
N	5720	420	2650	1290	570			
3P	4610	400	1410	690	410			
6	3670	360	890	430	310			
9	3720	350	630	310	240			
M	4010	320	490	240	190			
16-3A	4010	320	380	190	150			
6	4230	300	310	150	120			
9	4160	290	240	115	100			
N	2790	280	190	95	75			
3P	2160	280	135	65	50			
6	2010	280	90	45	40			
9	1860	275	60	30	25			
M	1740	270	40	20	15			
17-3A	1580	270	20	10	5			
6	1360	270	5	0	0			
9	1150	270	0	0	0			
TOTALS cfs /3 hrs	67640	8335	22960	11235	11235			

Assumed Normal Recession

DATE | COMPUTED BY

ENG FORM 1823
1 NOV 49

 50 6617



TIME HOUR	Q C.F.S.
10	420
12	195
15	155
18	150
21	135
24	110
36	50
48	0

CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE RESERVOIR

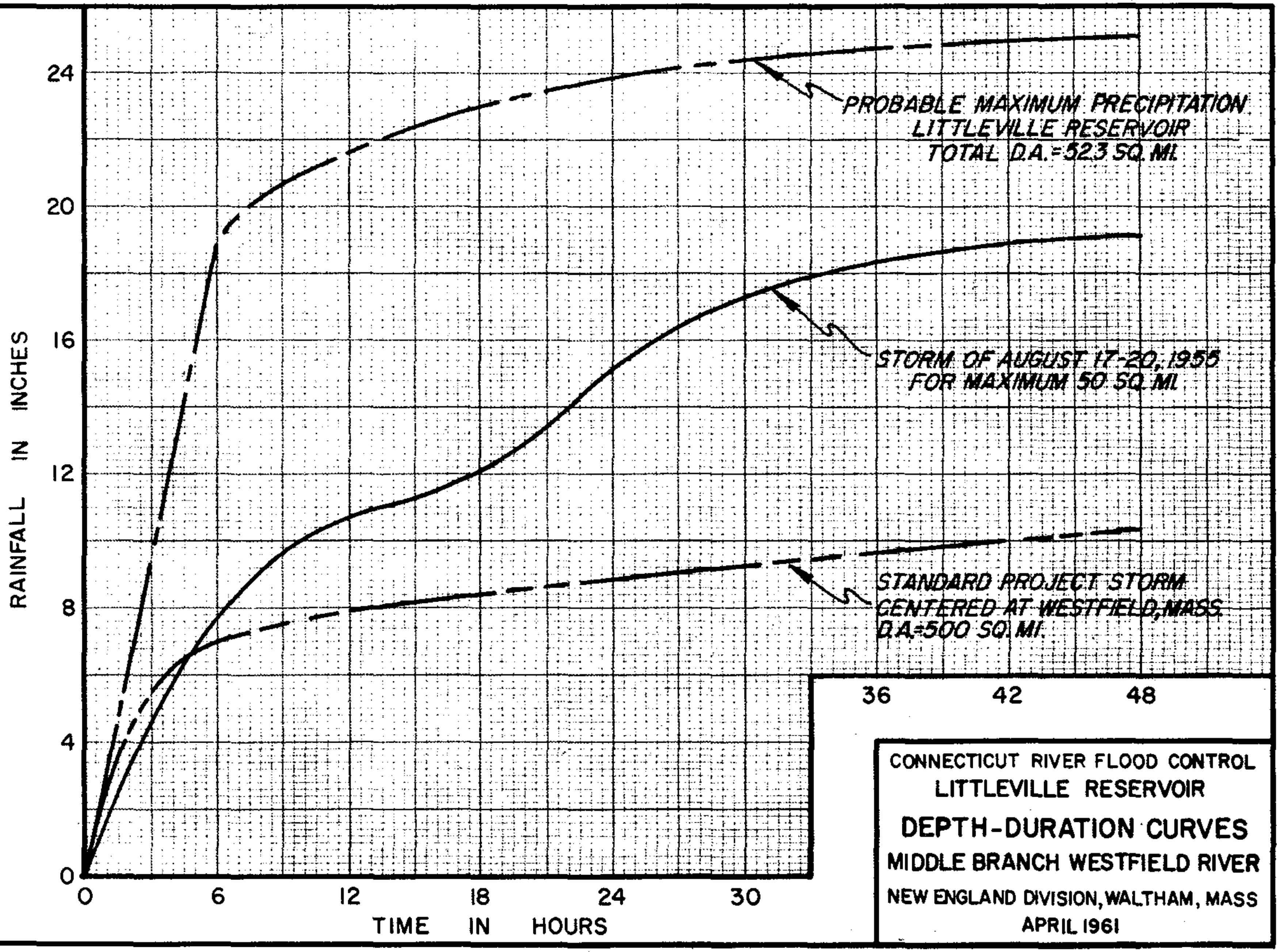
ADOPTED 3-HR. UNIT HYDROGRAPH

MIDDLE BRANCH WESTFIELD RIVER

NEW ENGLAND DIVISION, WALTHAM, MASS.

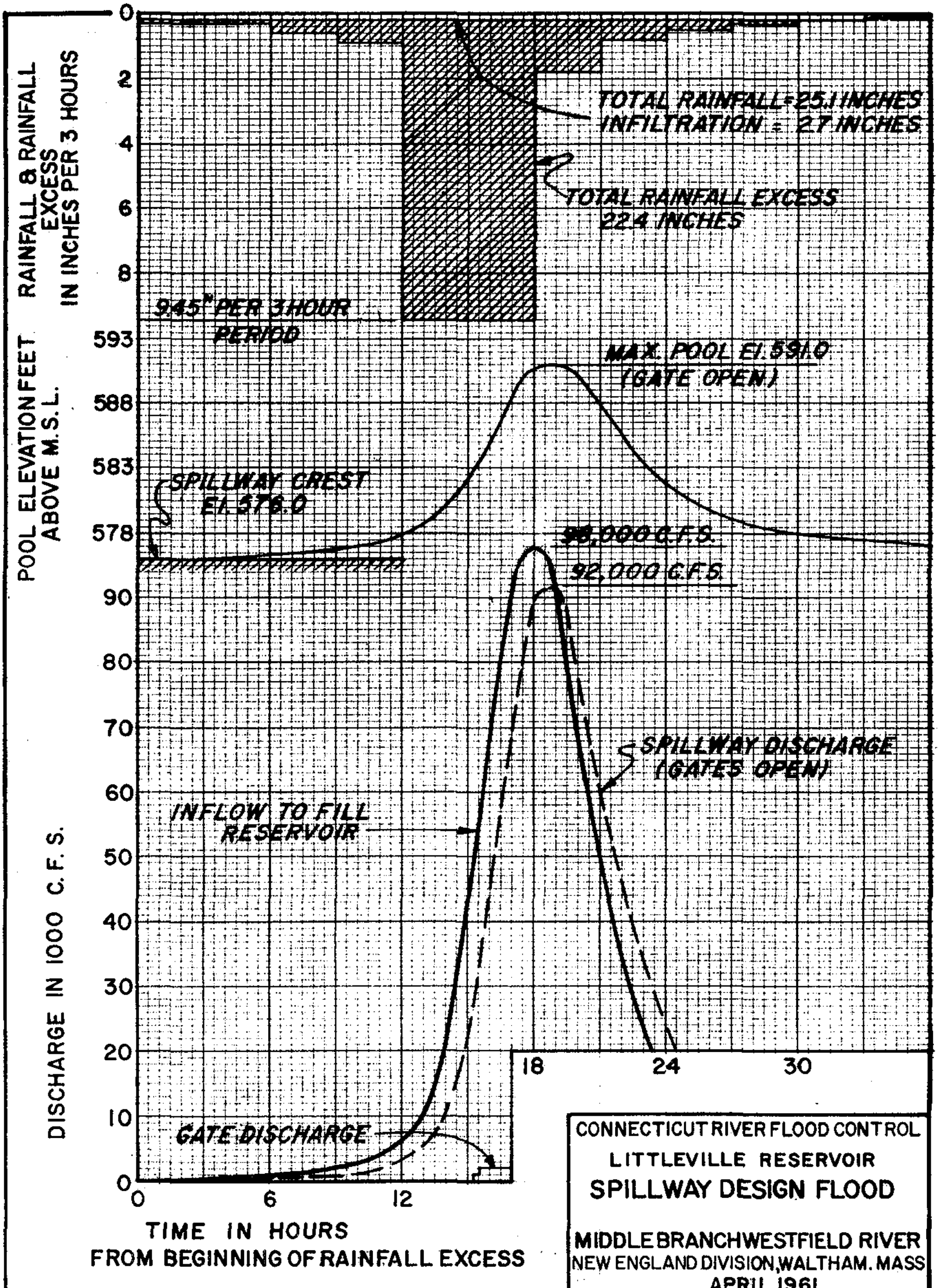
APRIL 1961

PLATE NO. I-20



CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE RESERVOIR
DEPTH-DURATION CURVES
MIDDLE BRANCH WESTFIELD RIVER
NEW ENGLAND DIVISION, WALTHAM, MASS
APRIL 1961

PLATE NO. I-21



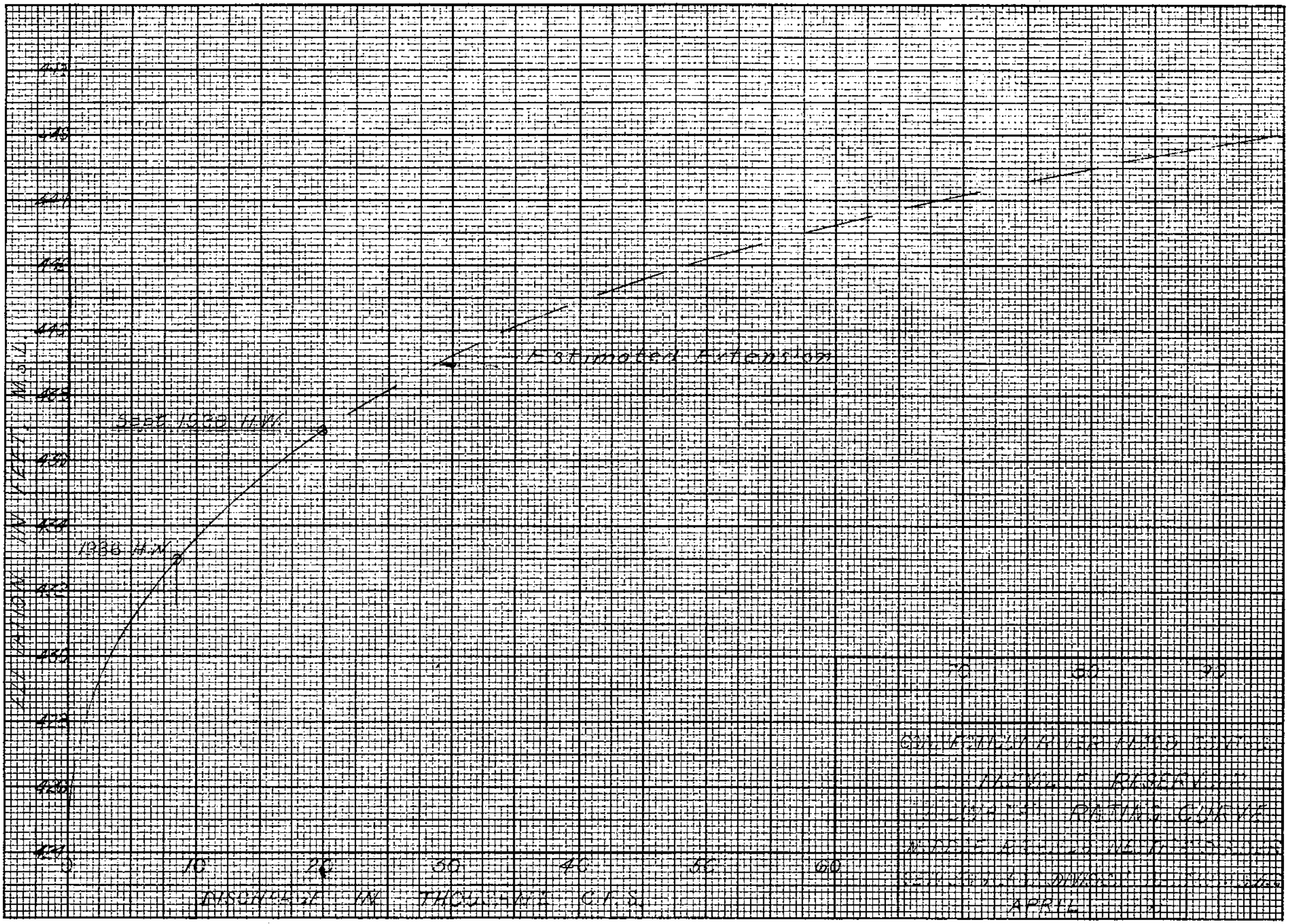
CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE RESERVOIR

SPILLWAY DESIGN FLOOD

MIDDLE BRANCH WESTFIELD RIVER
NEW ENGLAND DIVISION, WALTHAM. MASS
APRIL 1961

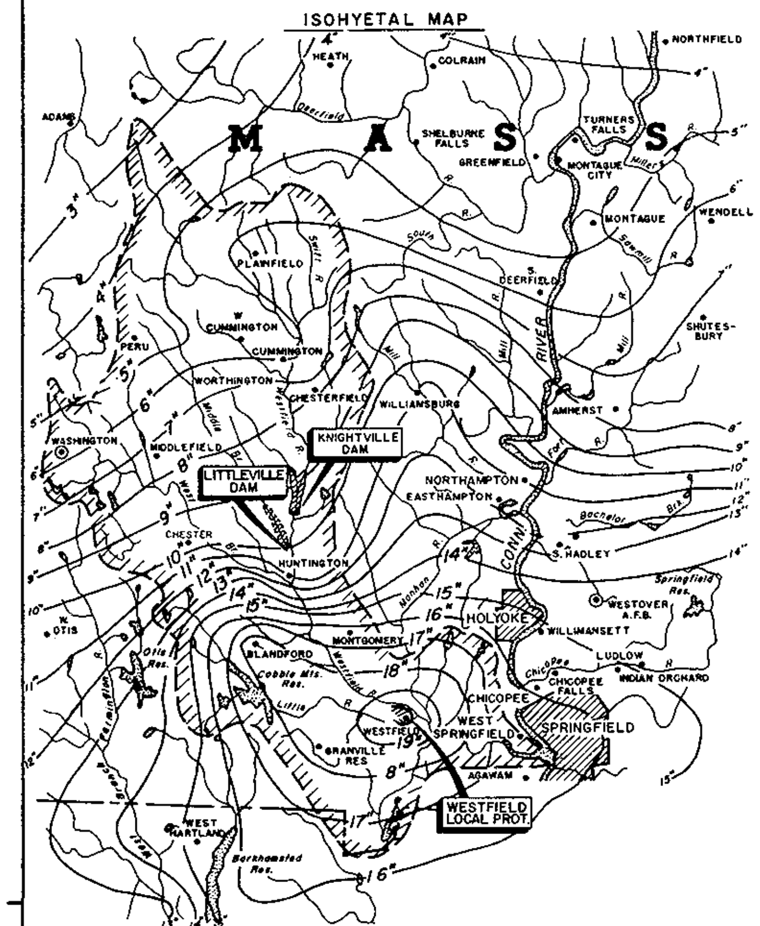
PLATE NO. I - 22



Estimated Extension
Sept 1938 H.W.
1936 H.W.
0
10
20
30
40
60
70
80
90
RATING CURVE
APRIL

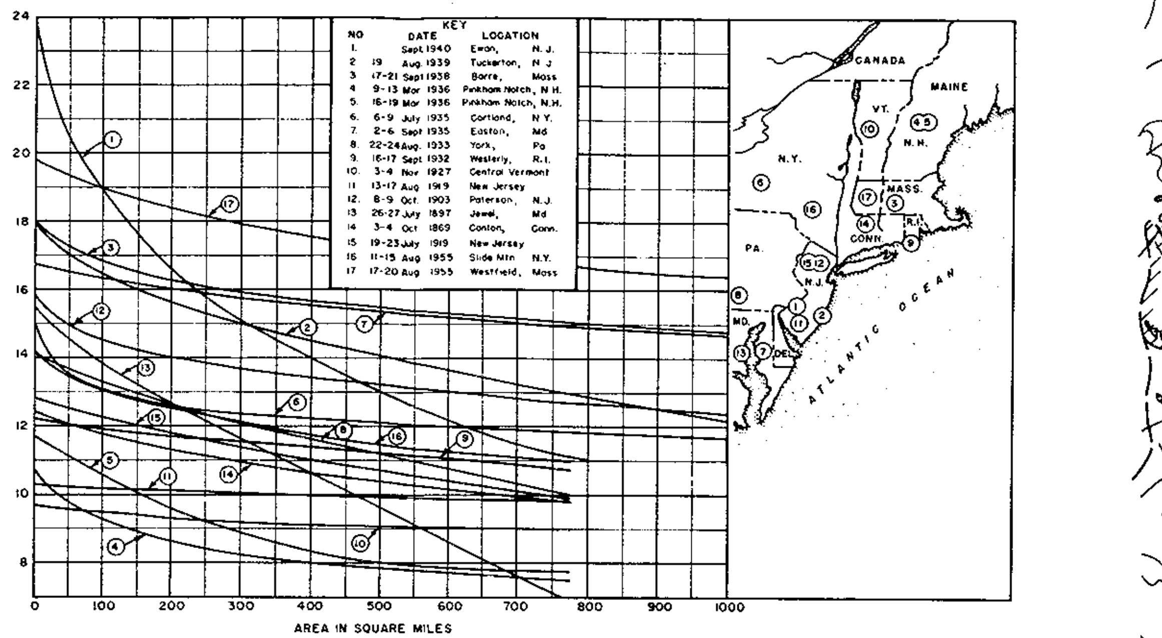
PLATE NO. I-23

CORPS OF ENGINEERS U.S. ARMY



TOTAL STORM ISOHYETALS
AUGUST 17-20 1955
(HURRICANE "DIANE")

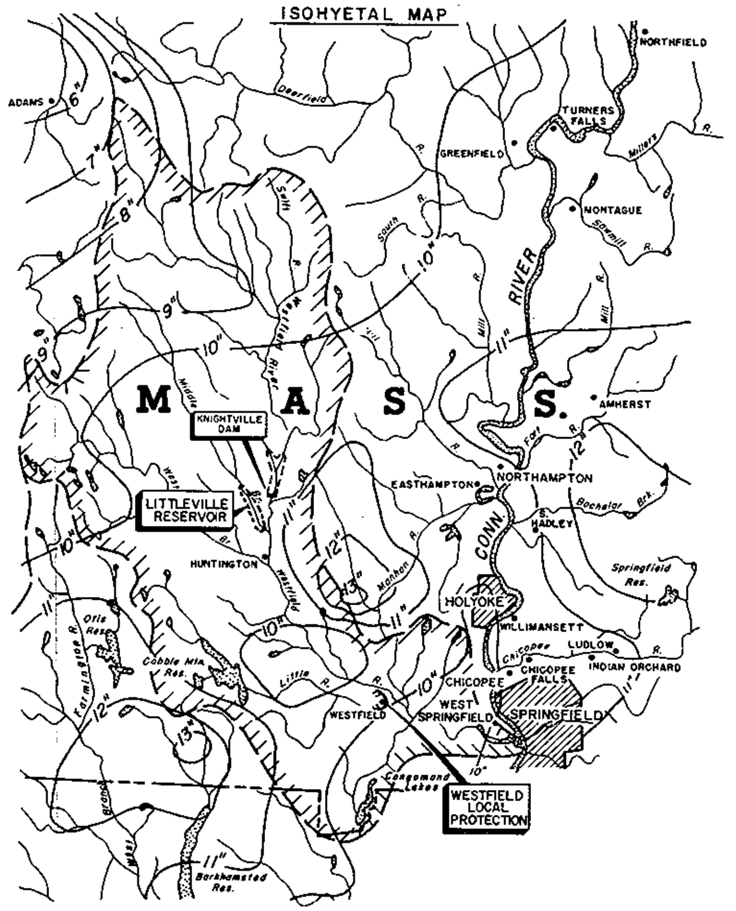
AREA-DEPTH CURVES
AND LOCATION OF STORM CENTERS



KEY

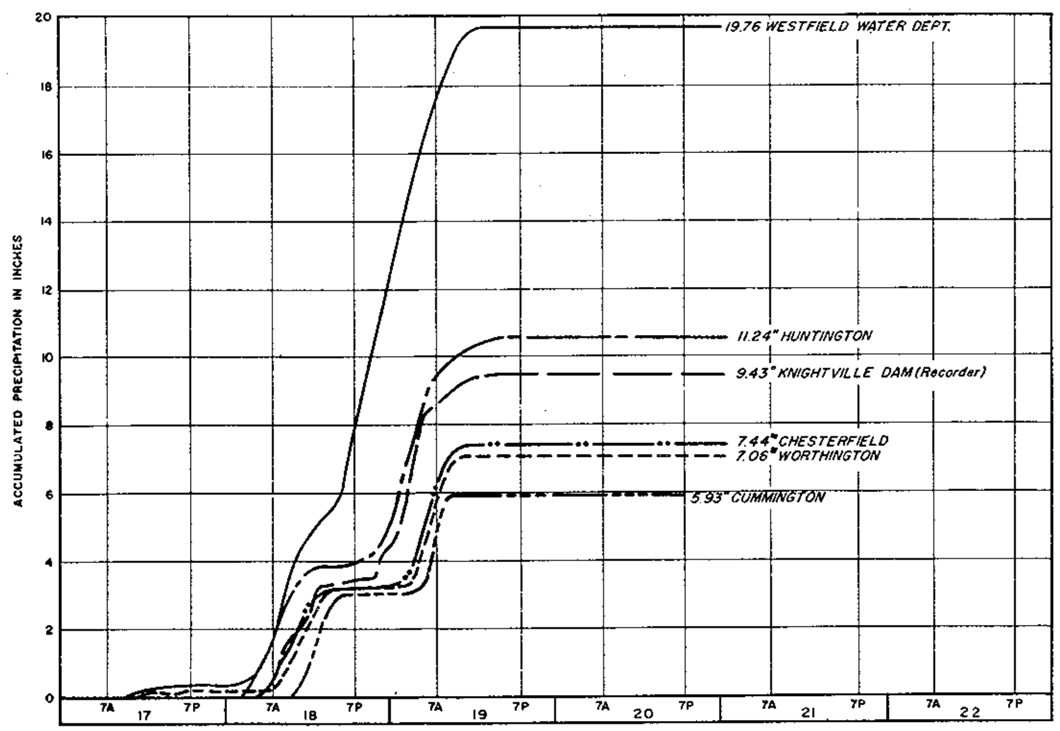
NO	DATE	LOCATION
1.	Sept 1940	Ewan, N. J.
2	19 Aug. 1939	Tuckerton, N J
3	17-21 Sept 1938	Barre, Mass
4	9-13 Mar 1936	Pinkham Notch, N H.
5.	16-19 Mar 1936	Pinkham Notch, N.H.
6.	6-9 July 1935	Cortland, N Y.
7.	2-6 Sept 1935	Easton, Md
8.	22-24 Aug. 1933	York, Pa
9.	16-17 Sept 1932	Westerly, R.I.
10.	3-4 Nov 1927	Central Vermont
11	13-17 Aug 1919	New Jersey
12.	8-9 Oct. 1903	Paterson, N.J.
13	26-27 July 1897	Jewel, Md
14	3-4 Oct 1869	Canton, Conn.
15	19-23 July 1919	New Jersey
16	11-15 Aug 1955	Slide Mtn N.Y.
17	17-20 Aug 1955	Westfield, Mass

STORMS OF RECORD
NORTHEASTERN UNITED STATES

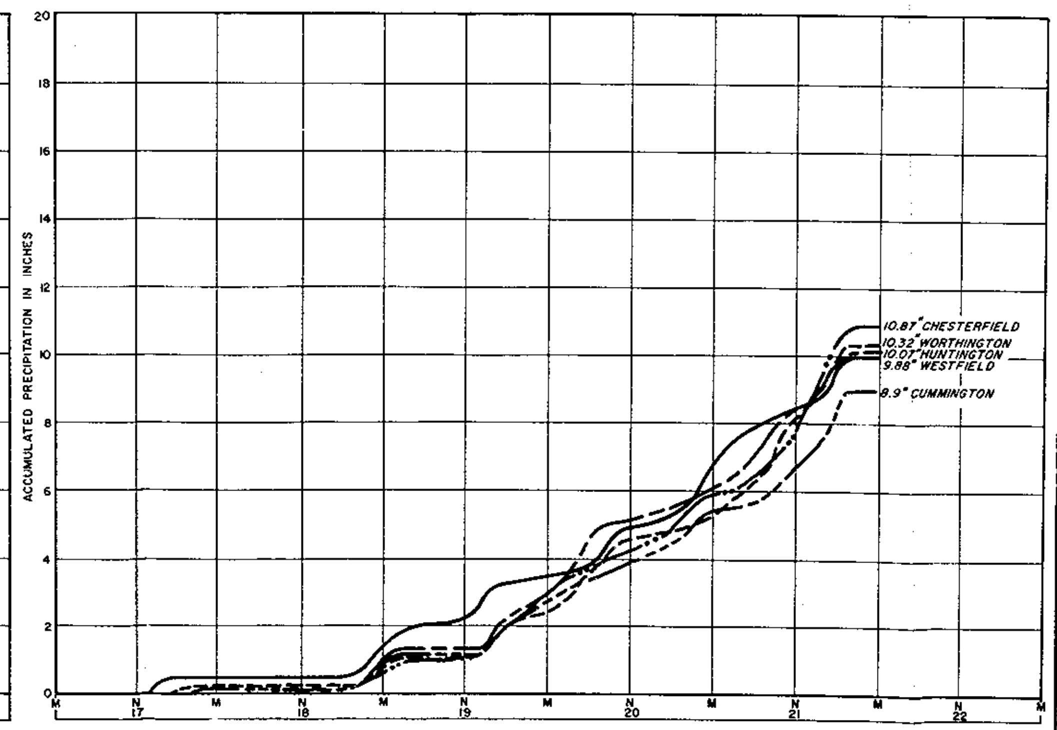


TOTAL STORM ISOHYETALS
SEPTEMBER 17-22, 1938

MASS CURVES



AUGUST 1955



SEPTEMBER 1938

REVISION	DATE	DESCRIPTION	BY

CORPS OF ENGINEERS. U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
WALTHAM, MASS.

DR BY | TR. BY S.J.C. | CK. BY E.P.S.

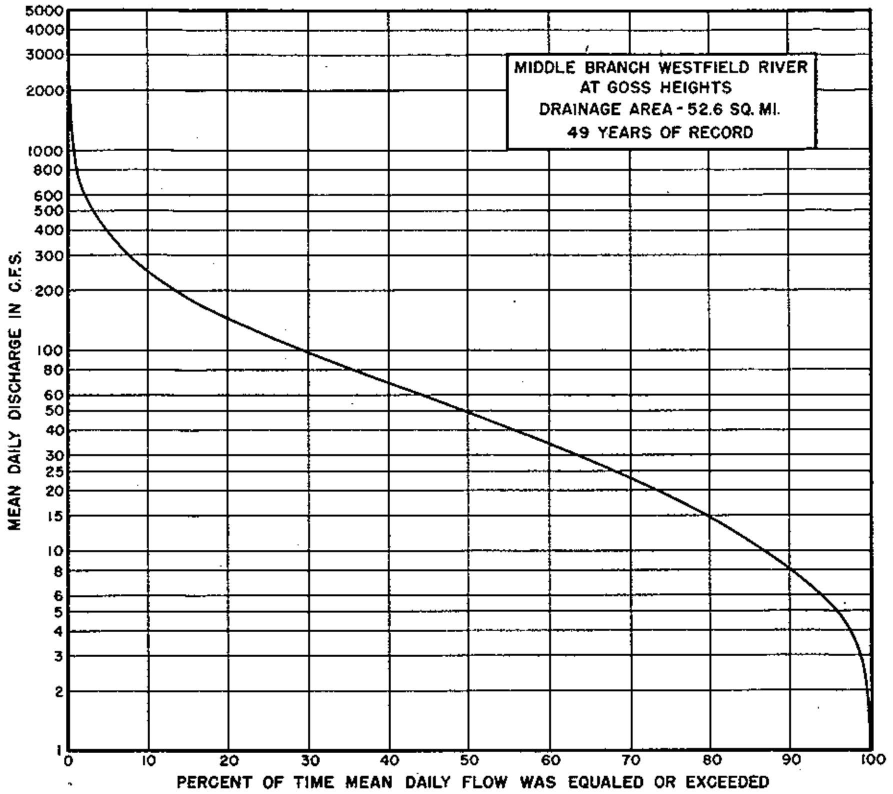
SUBMITTED
PROJECT ENGINEER
APPROVAL RECOMMENDED
CHIEF, HYD. & HYD. SECTION
APPROVAL RECOMMENDED
CHIEF P & R BRANCH

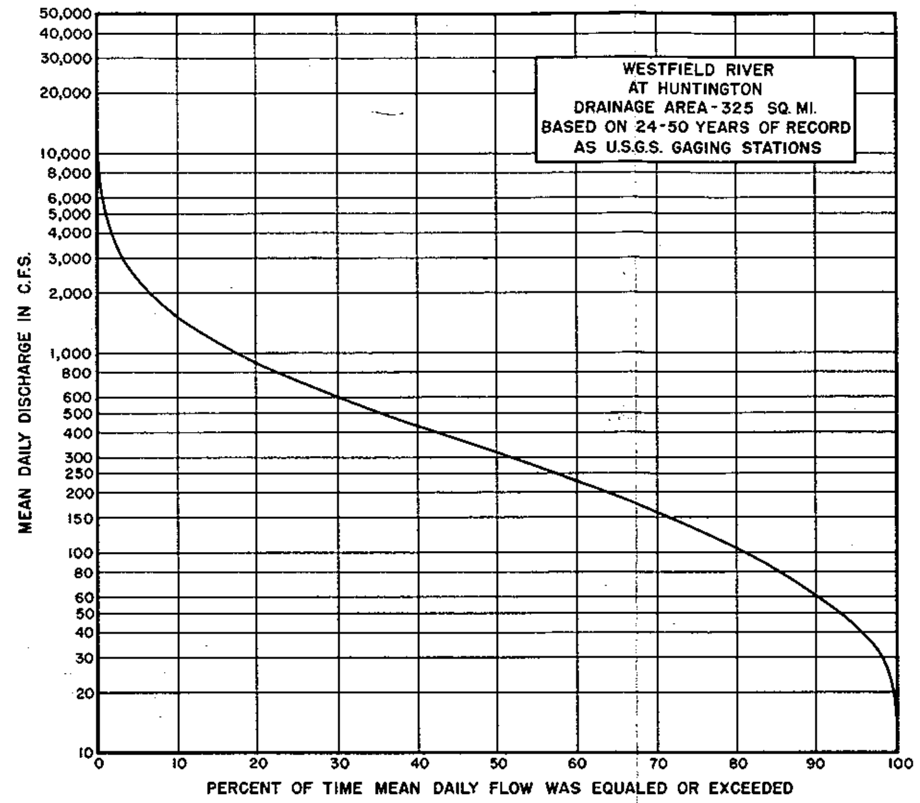
CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE RESERVOIR
HYDROLOGIC DATA FOR RECORD STORMS
MIDDLE BRANCH WESTFIELD RIVER, MASS.

APPROVED
CHIEF ENGINEERING DIVISION
DATE APRIL 1961

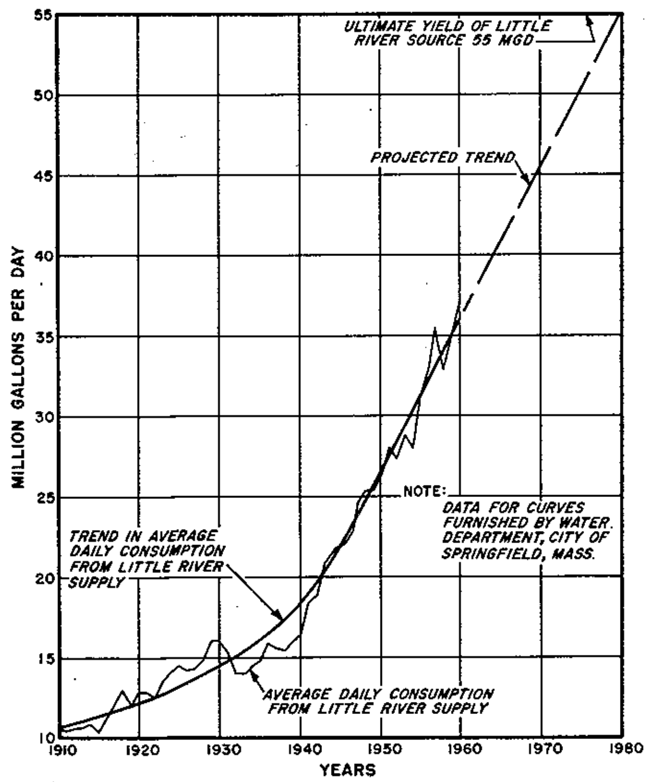
SCALE AS NOTED.
DRAWING NUMBER
CT-1-4571
SHEET 1 OF 1

PLATE NO. I-24

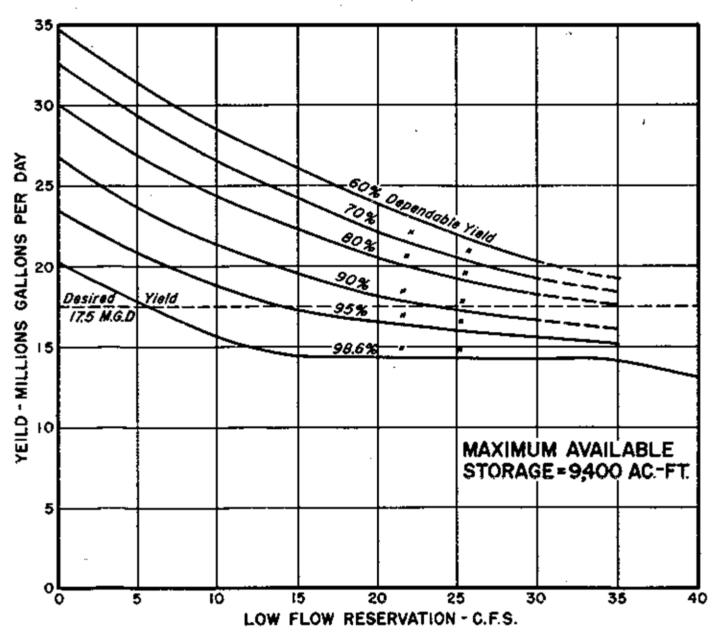




FLOW — DURATION CURVES



TREND IN AVERAGE DAILY WATER CONSUMPTION - (1910-1980)



DEPENDABLE YIELD VS. LOW FLOW RESERVATION

NOTES:

1. *Dependability of Yield is the statistical probability of satisfying a continuous water supply demand from the Middle Branch with a limited storage of 9,400 acre-feet in Littleville Reservoir.*
2. *Low Flow Reservation is that rate of discharge in the Middle Branch, below which natural stream flow may not be further decreased for water supply purposes. Specific rate of low flow reservation will be ultimately prescribed by the Massachusetts Water Resources Commission.*

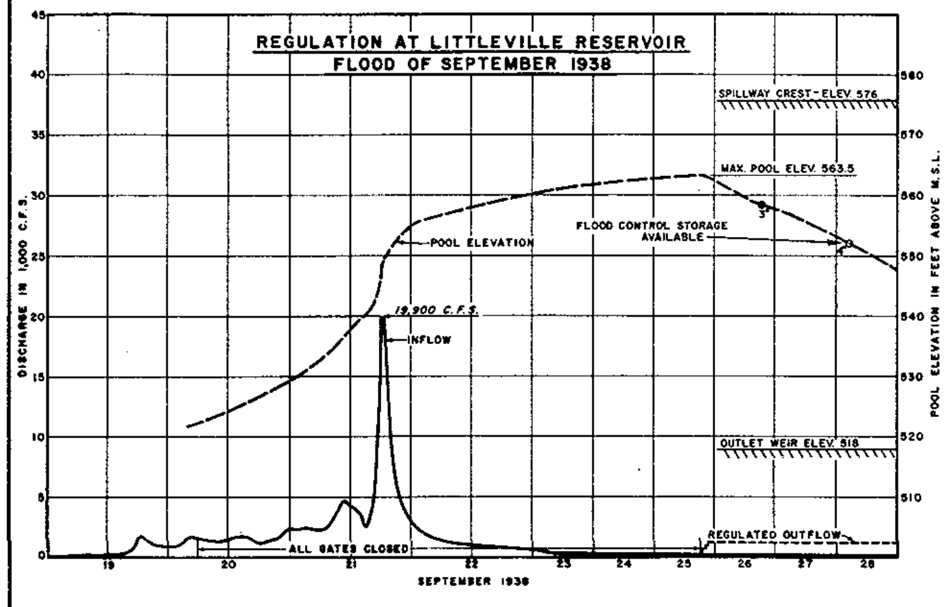
REVISION	DATE	DESCRIPTION	BY

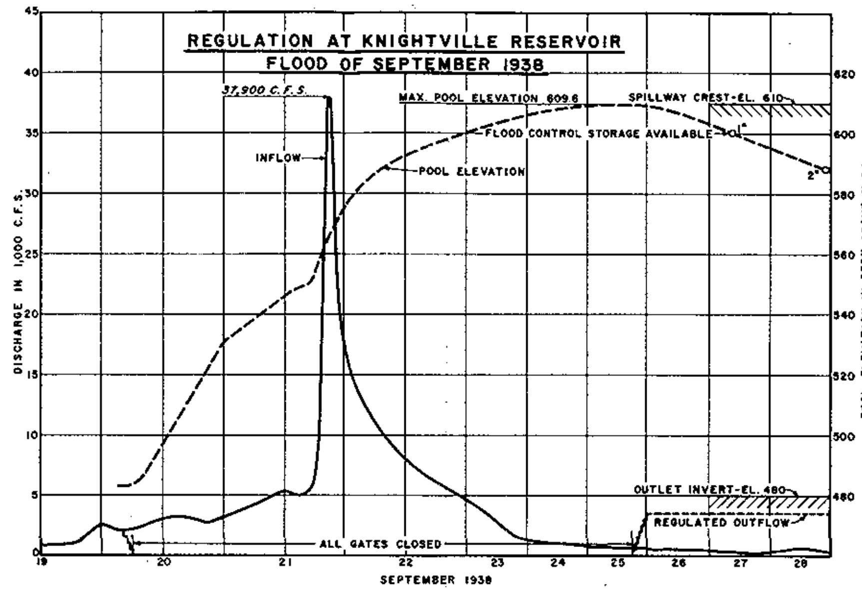
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

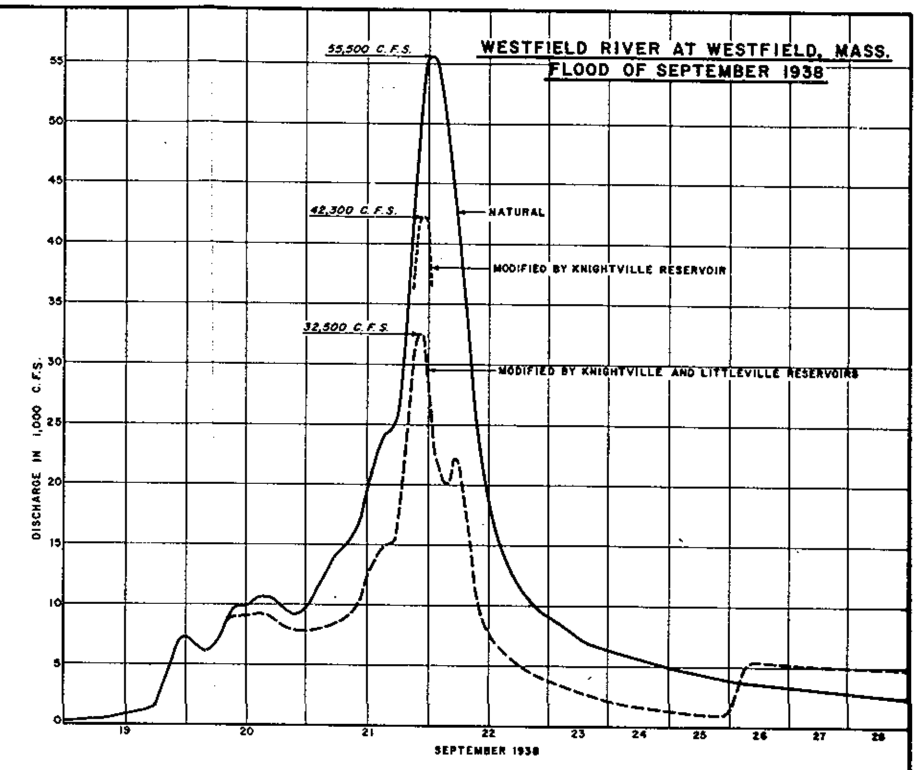
DR. BY | TR. BY M.S. | CK. BY
SUBMITTED
CHIEF, HYD. & HYD. SECTION
PROJECT ENGINEER
CHIEF, SECTION
SUBMITTED BY
CHIEF, PLANN. & RPTS. BRANCH

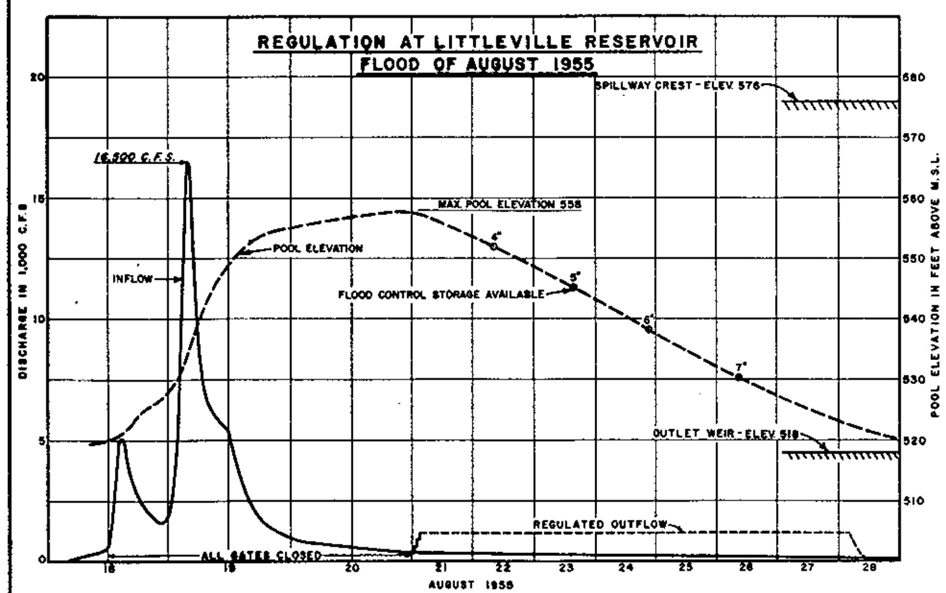
CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE RESERVOIR
HYDROLOGIC DATA FOR WATER SUPPLY
MIDDLE BRANCH WESTFIELD RIVER, MASS.

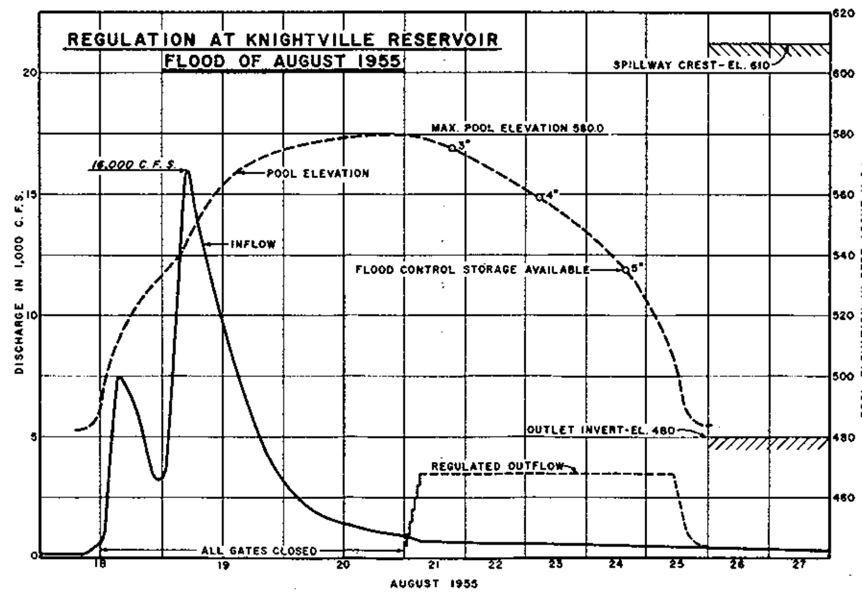
APPROVED DATE APRIL 1961
CHIEF, ENGINEERING DIV.
SCALE | SPEC. NO. CIV. ENG.-19-016-
DRAWING NUMBER
SHEET

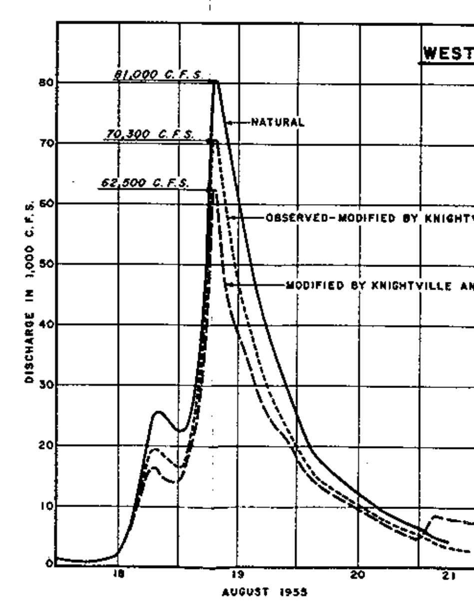












CONNECTICUT RIVER FLOOD CONTROL
WESTFIELD RIVER WATERSHED.

LITTLEVILLE RESERVOIR

RESERVOIR REGULATION

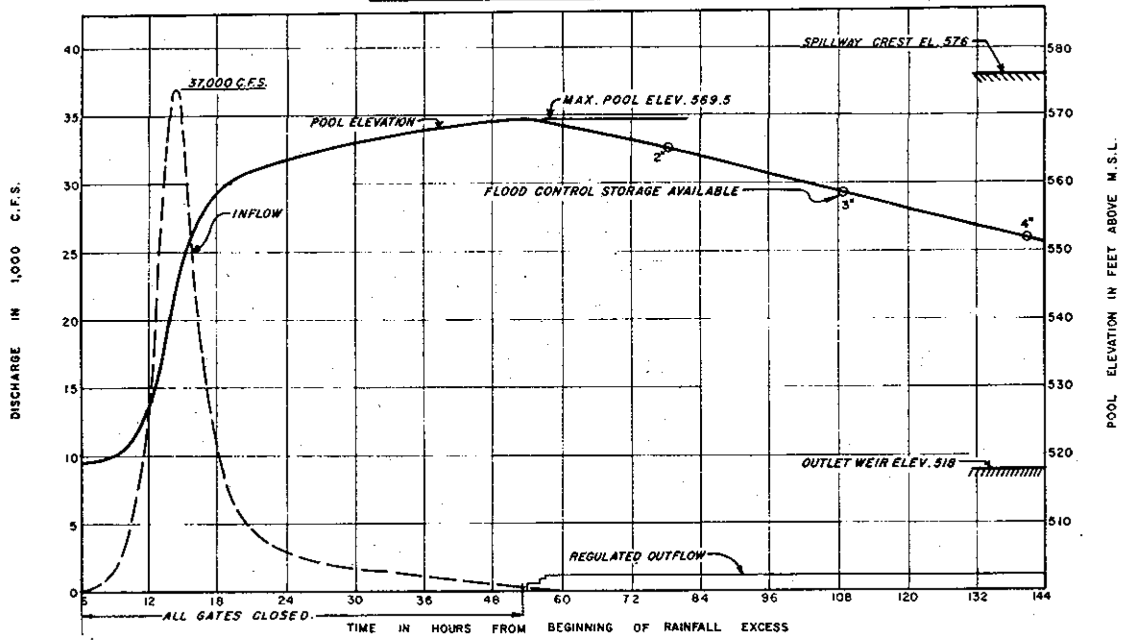
SEPTEMBER 1938 & AUGUST 1955 FLOODS

MIDDLE BRANCH WESTFIELD RIVER, MASS.

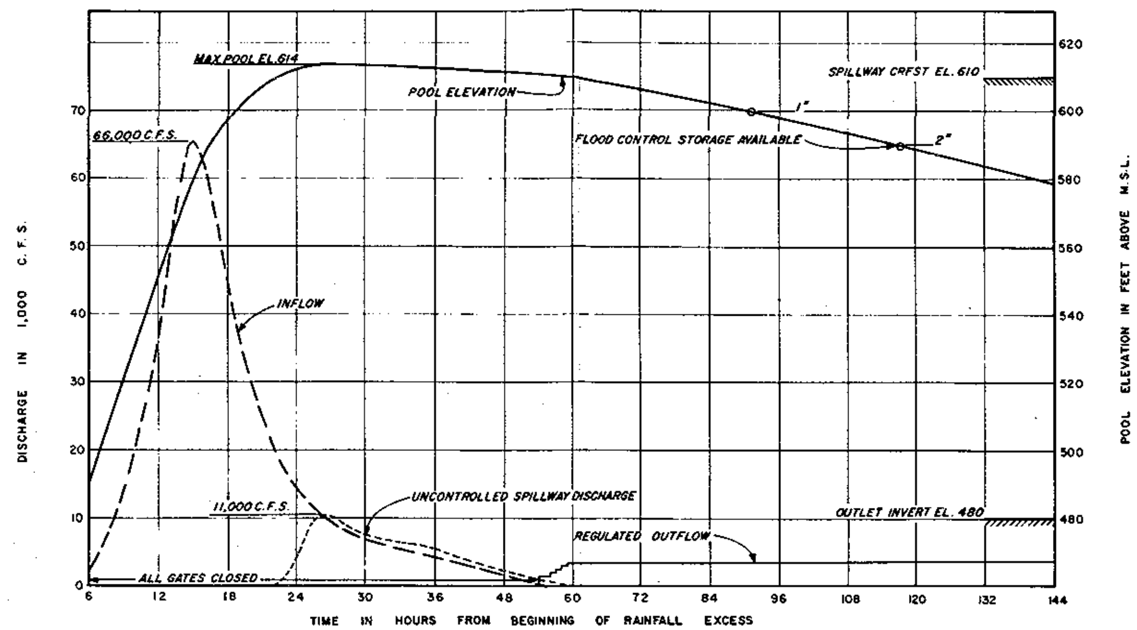
CORPS OF ENGINEERS, U.S. ARMY
NEW ENGLAND DIVISION
WALTHAM, MASS.
APRIL 1961

PLATE NO. I-26

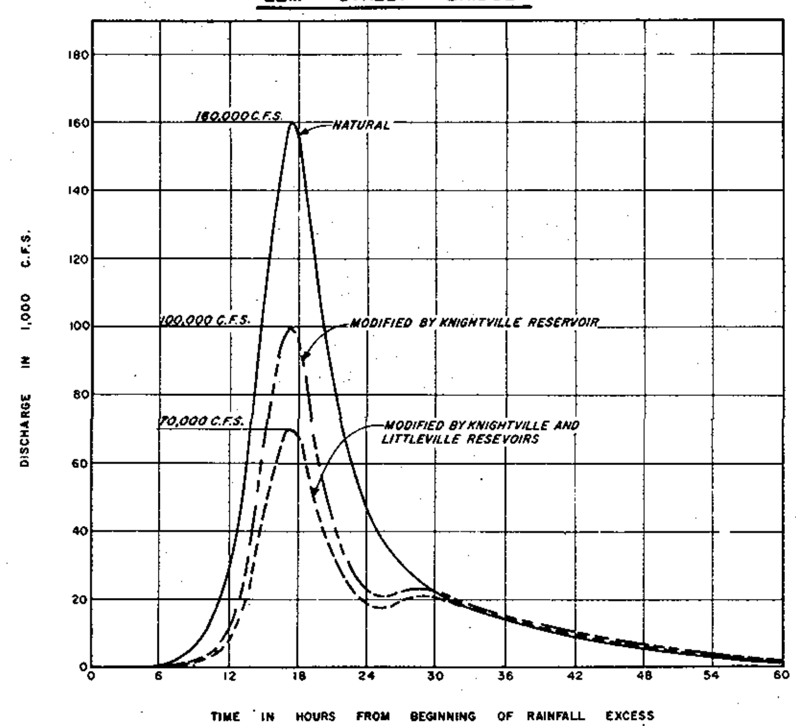
REGULATION AT LITTLEVILLE RESERVOIR



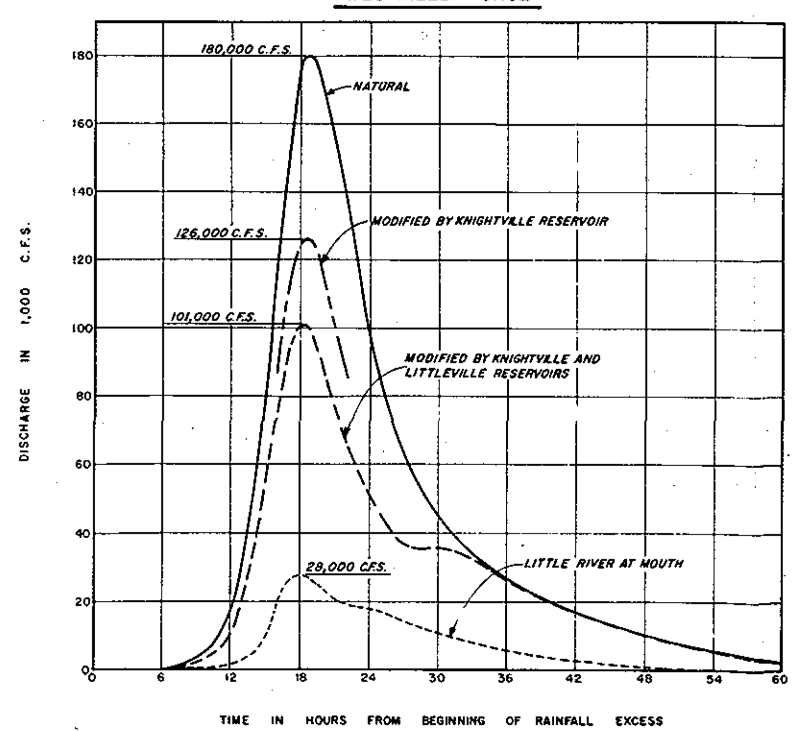
REGULATION AT KNIGHTVILLE RESERVOIR



WESTFIELD RIVER AT ELM STREET BRIDGE



WESTFIELD RIVER AT WESTFIELD GAGE



REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

DR. BY	TR. BY	CK. BY
E.P.S.	M.W.S.	E.P.S.

SUBMITTED:

PROJECT ENGINEER

APPROVAL RECOMMENDED

CHIEF, HYD. & HYD. SECTION

APPROVAL RECOMMENDED

CHIEF PLANNING & REPORTS BR.

CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE RESERVOIR

RESERVOIR REGULATION

STANDARD PROJECT FLOOD

MIDDLE BRANCH WESTFIELD RIVER, MASS.

APPROVED:

CHIEF ENGINEERING DIVISION

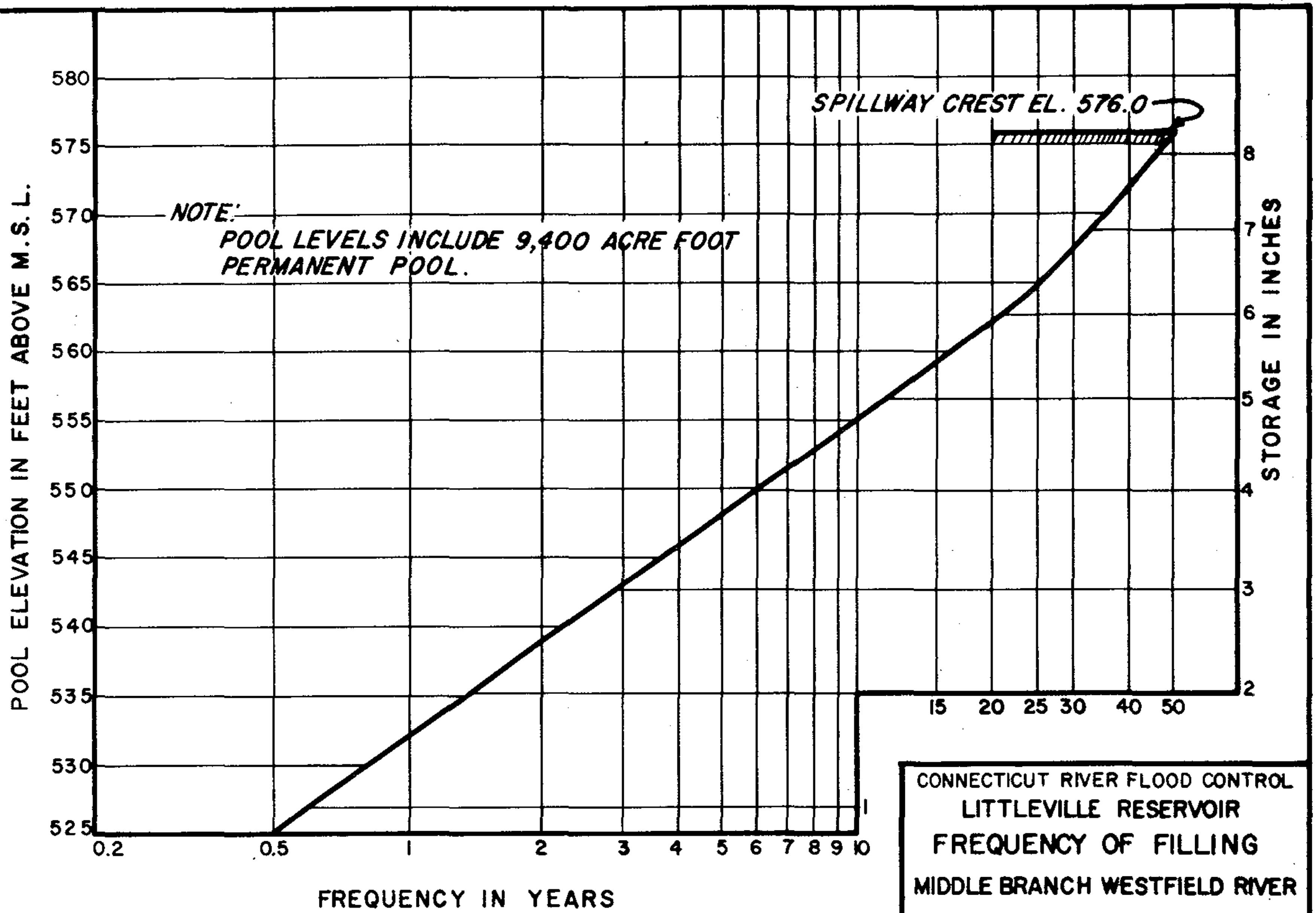
DATE APRIL 1961

SCALE AS NOTED

DRAWING NUMBER

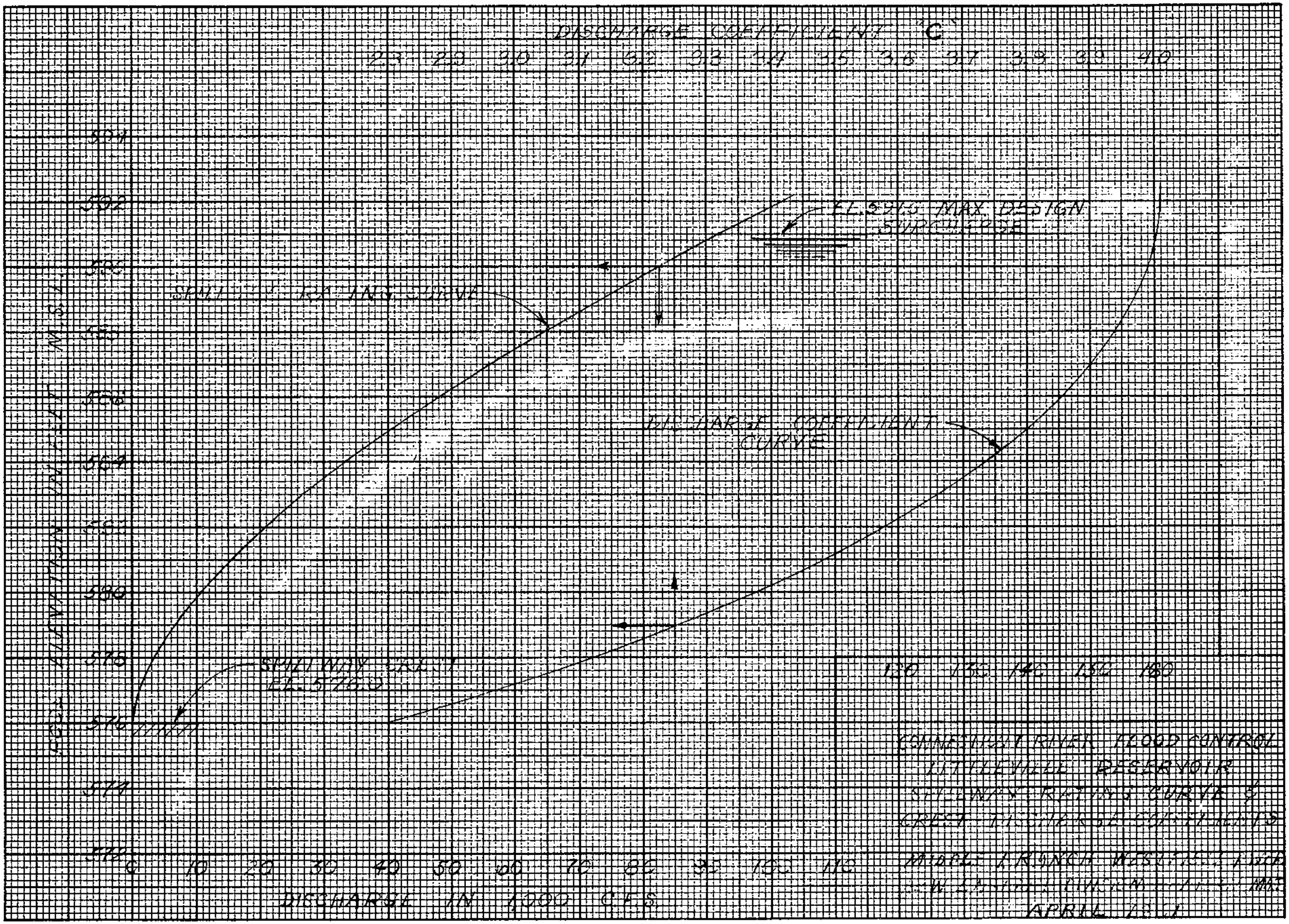
CT-1-4572

SHEET 1 OF 1



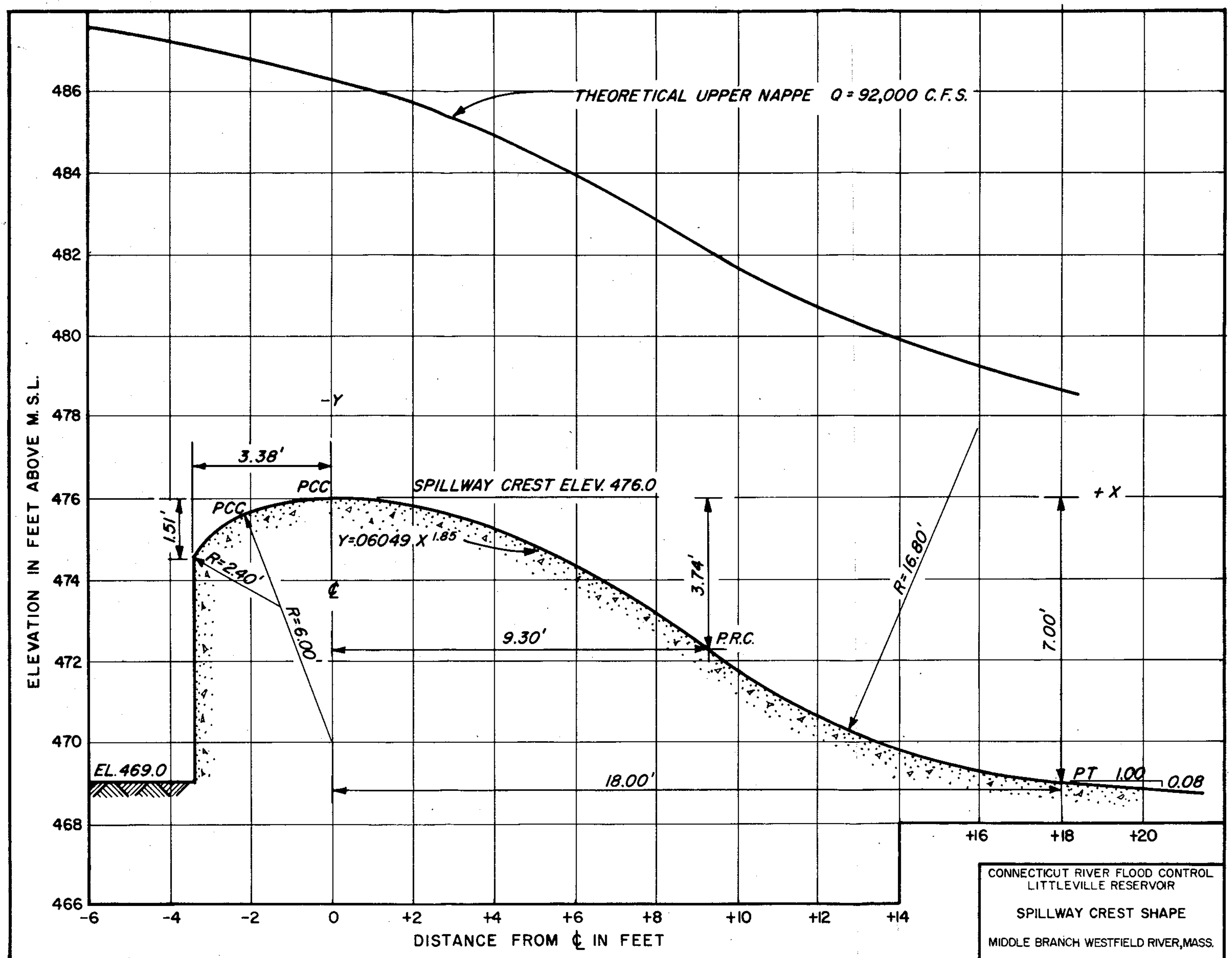
CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE RESERVOIR
FREQUENCY OF FILLING
MIDDLE BRANCH WESTFIELD RIVER
NEW ENGLAND DIVISION, WALTHAM, MASS.
APRIL 1961

PLATE NO. I - 28



DISCHARGE COEFFICIENT "C"
30
31
32
33
34
35
36
37
39
40
594
592
586
584
580
578
576
574
SPILLWAY RATING CURVE
MAX DESIGN SURCHARGE
DISCHARGE COEFFICIENT CURVE
SPILLWAY CREST
0
10
20
30
40
50
60
70
80
100
110
130
140
150
160
DISCHARGE IN 1000 CFS
CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE RESERVOIR
SPILLWAY RATING CURVE &
APRIL

PLATE NO. I-29



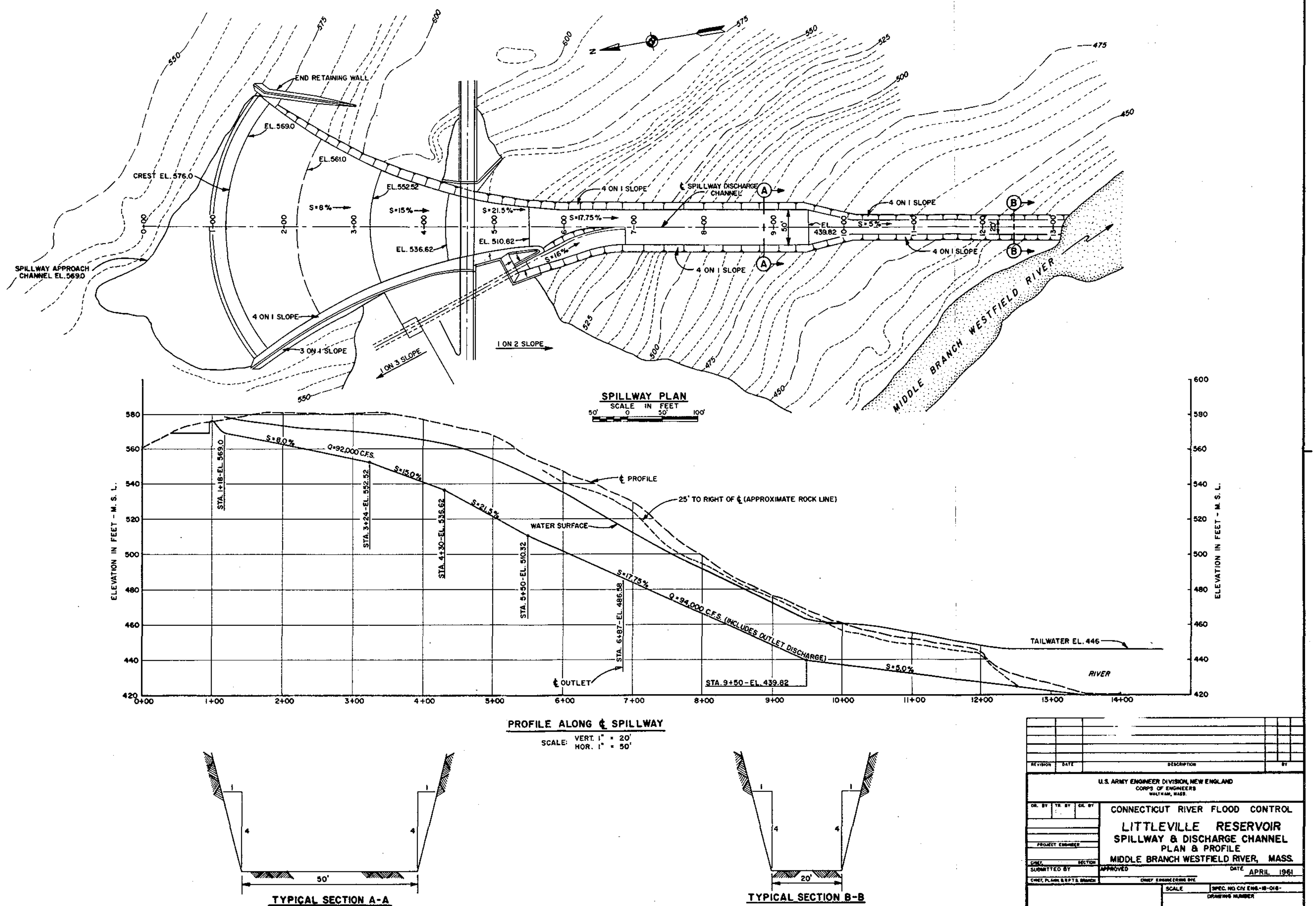
CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE RESERVOIR

SPILLWAY CREST SHAPE

MIDDLE BRANCH WESTFIELD RIVER, MASS.

NEW ENGLAND DIVISION, WALTHAM, MASS.
APRIL 1961

PLATE NO. I-30



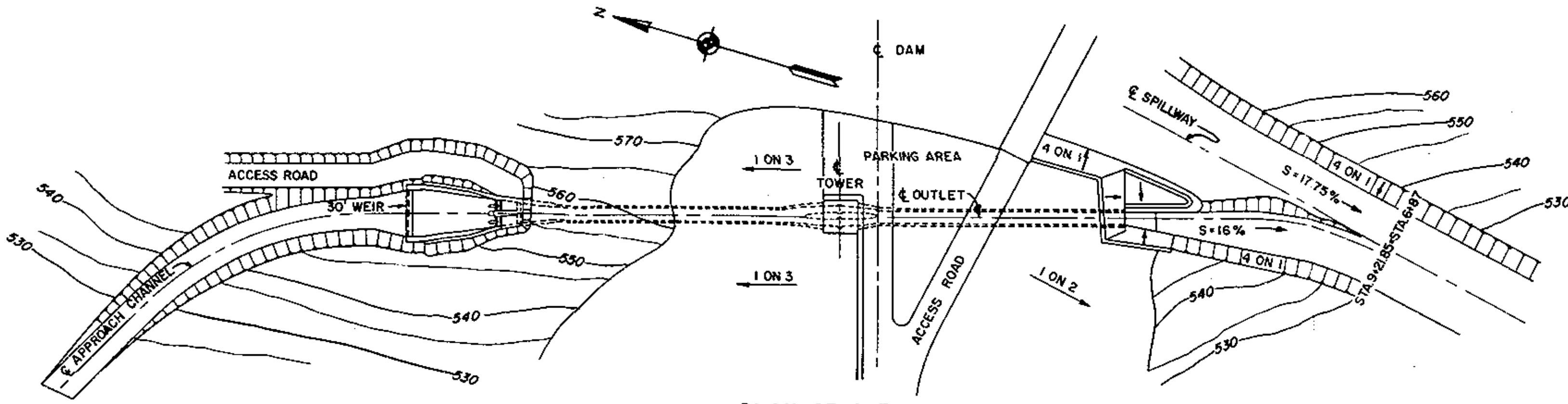
REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

CONNECTICUT RIVER FLOOD CONTROL
LITTLEVILLE RESERVOIR
SPILLWAY & DISCHARGE CHANNEL
PLAN & PROFILE
MIDDLE BRANCH WESTFIELD RIVER, MASS.

DR. BY | TR. BY | CK. BY
PROJECT ENGINEER
CHIEF, SECTION
SUBMITTED BY
APPROVED
DATE APRIL 1961
CHIEF, PLANN. & R.P.T.S. BRANCH
CHIEF, ENGINEERING DIV.
SCALE
SPEC. NO. CIV. ENG-19-016-
DRAWING NUMBER
SHEET

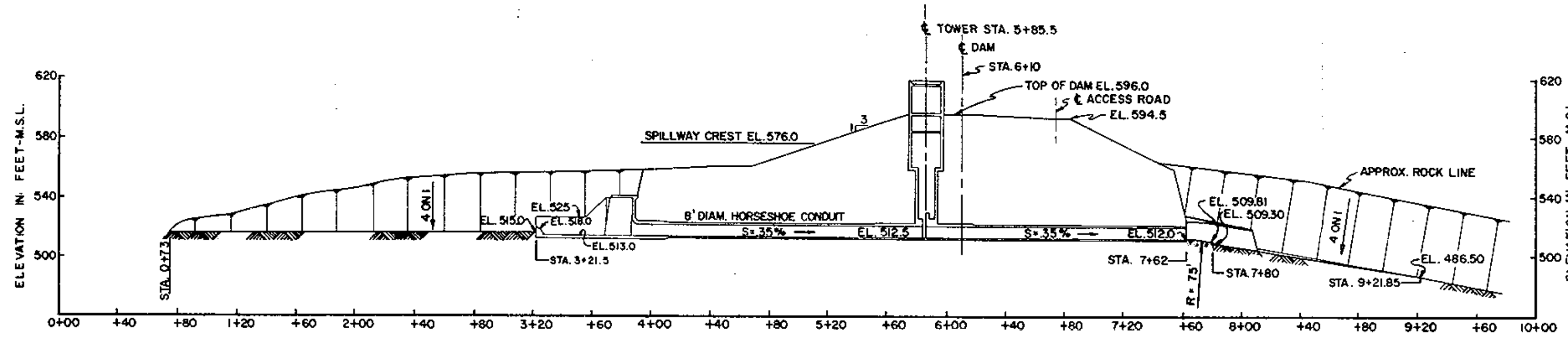
PLATE NO. I-31



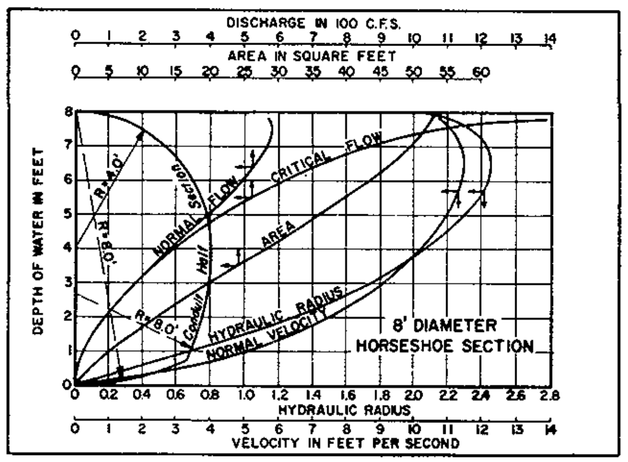
PLAN OF OUTLET WORKS

SCALE IN FEET

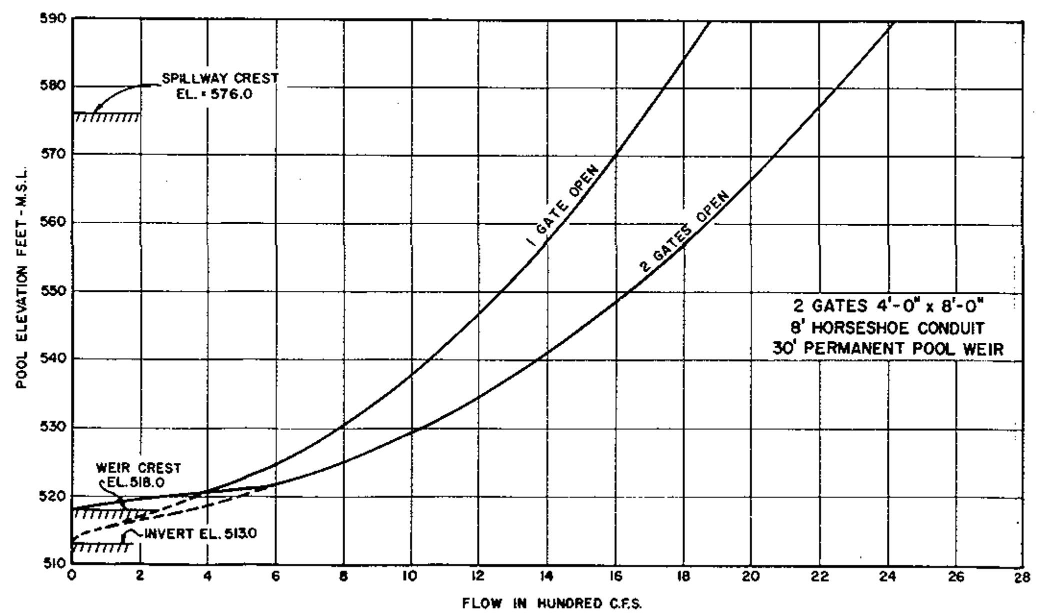
40 0 40 80



PROFILE ALONG ℄ OUTLET WORKS



HYDRAULIC ELEMENTS CURVES



OUTLET RATING CURVES

REVISION	DATE	DESCRIPTION	BY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS

DR. BY J.W.F. | TR. BY | CK. BY R.W.M.

CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE RESERVOIR

FLOOD CONTROL OUTLET WORKS

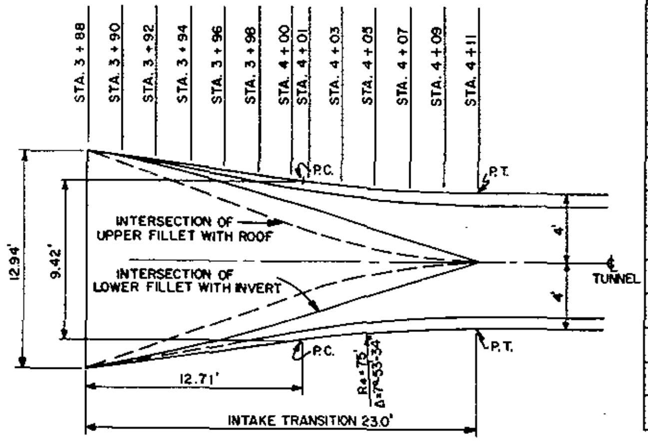
MIDDLE BRANCH WESTFIELD RIVER, MASS.

APPROVED — DATE APRIL 1961

SCALE — SPEC. NO. CIV ENG-19-016-

DRAWING NUMBER

SHEET



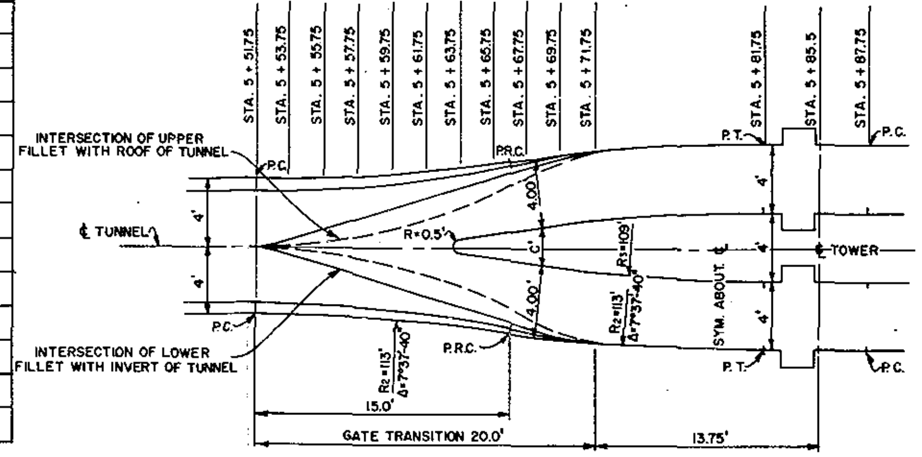
PLAN

STATION	D	R_1	a	b
4+11	8.00	4.00	0.71	3.29
4+09	8.05	3.96	0.70	2.79
4+07	8.21	3.83	0.68	2.24
4+05	8.48	3.61	0.64	1.77
4+03	8.86	3.31	0.59	1.37
4+01	9.34	2.92	0.52	1.01
4+00	9.62	2.69	0.48	0.86
3+98	10.17	2.24	0.40	0.61
3+96	10.72	1.79	0.32	0.42
3+94	11.28	1.35	0.24	0.27
3+92	11.83	0.90	0.16	0.16
3+90	12.39	0.45	0.08	0.07
3+88	12.94	0.00	0.00	0.00

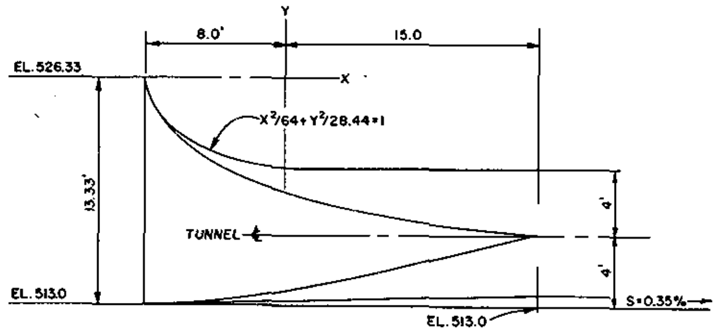
INTAKE TRANSITION DIMENSIONS

STATION	STATION	D−c	R_1	a	b
5+51.75	6+17.75	8.00	4.00	0.71	3.29
5+53.75	6+15.75	8.03	3.96	0.70	2.84
5+55.75	6+13.75	8.14	3.82	0.68	2.30
5+57.75	6+11.75	8.32	3.59	0.64	1.82
5+59.75	6+09.75	8.57	3.27	0.58	1.45
5+61.75	6+07.75	8.89	2.86	0.51	1.08
GATE TUNNEL DIMENSIONS WHERE C>0					
5+63.75	6+05.75	8.28	2.36	0.42	0.77
5+65.75	6+03.75	8.01	1.76	0.31	0.49
5+67.75	6+01.75	8.00	1.10	0.20	0.26
5+69.75	5+99.75	8.00	0.50	0.09	0.10
5+71.75	5+97.75	8.00	0.00	0.00	0.00
5+81.75	5+87.75	8.00	0.00	0.00	0.00

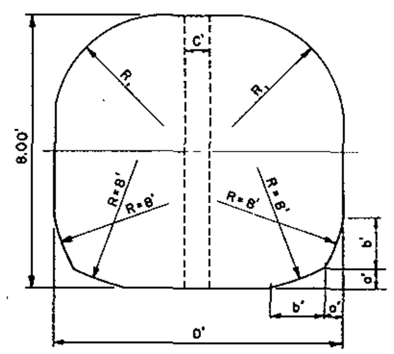
GATE TRANSITION DIMENSIONS



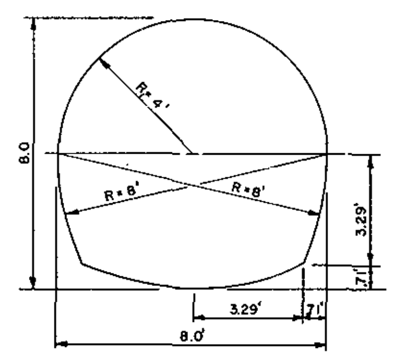
PLAN
(UPSTREAM GATE TUNNEL TRANSITION)



ELEVATION
INTAKE TRANSITION
SCALE IN FEET

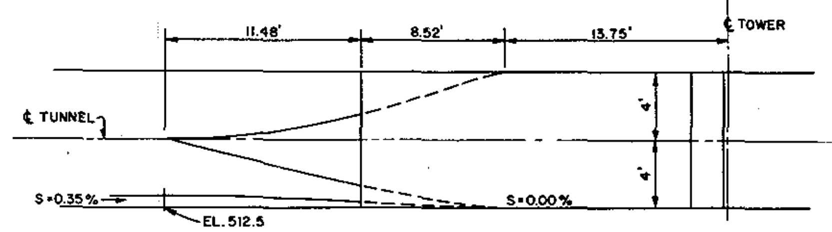


TYPICAL TRANSITION SECTION

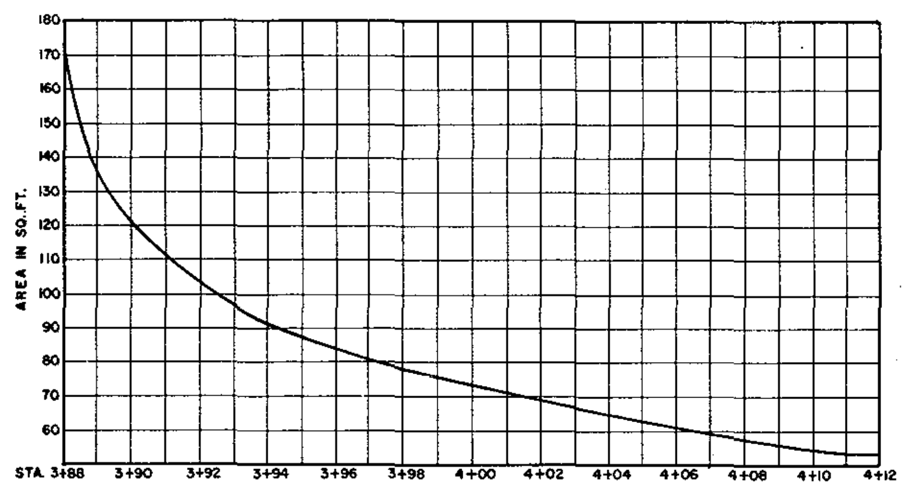


TYPICAL CONDUIT SECTION

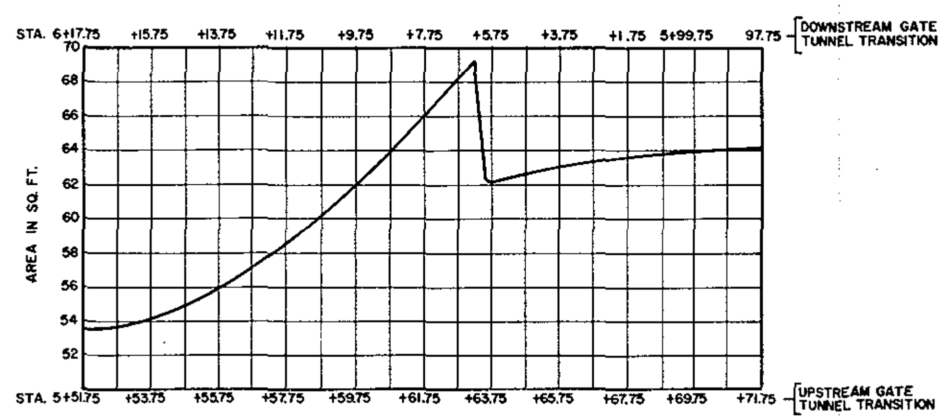
SCALE IN FEET



ELEVATION
GATE TRANSITION
SCALE IN FEET



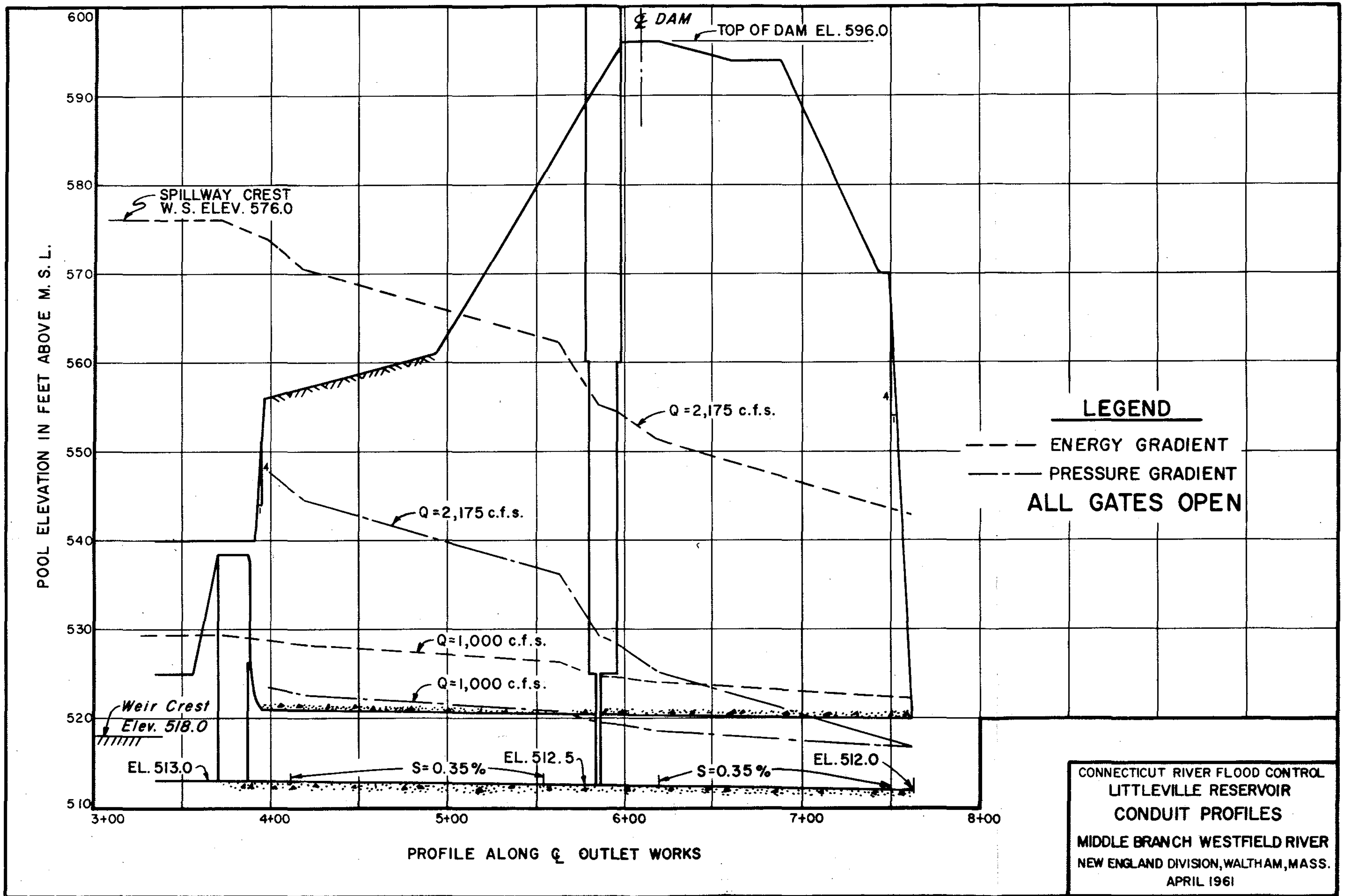
INTAKE TRANSITION AREA CURVE



GATE TRANSITION AREA CURVE

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND CORPS OF ENGINEERS WALTHAM, MASS.		
DR. BY R.W.M. / TR. BY F.L.C. / CK. BY R.W.M.	CONNECTICUT RIVER FLOOD CONTROL LITTLEVILLE RESERVOIR OUTLET TRANSITIONS MIDDLE BRANCH WESTFIELD RIVER, MASS.	
PROJECT ENGINEER		
SUBMITTED BY	APPROVED	DATE APRIL 1961
CHIEF, PLANNING & REPTS BRANCH	CHIEF ENGINEERING DIV.	
SCALE	SPEC. NO. CIV. ENG.-19-016-	DRAWING NUMBER

PLATE NO. I-33



CONNECTICUT RIVER FLOOD CONTROL

LITTLEVILLE RESERVOIR

CONDUIT PROFILES

MIDDLE BRANCH WESTFIELD RIVER

NEW ENGLAND DIVISION, WALTHAM, MASS.

APRIL 1961

PLATE NO. I-34